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Proceedings of the

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June 5 to 9, 1922

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EARL L. SHANER

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ROBERT E. KENNEDY

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Summary of the Proceedings of the Twenty-sixth Annual Meeting

Rochester, N. Y., June 5 to 9, 1922

After a lapse of a year and a half since the previous convention, the twenty-sixth annual meeting of the American Foundrymen's association was happily held at a time when the general industrial depression, prevailing since the Columbus meeting, was giving way to a marked improvement.

The attendance and registration at both the technical sessions and exhibits were large, having been exceeded only on two previous occasions. The exhibition, although not the largest, was one of the most representative ever held.

The convention marked an epoch in the history of the association in that it presented the first specially planned international session. Featured by the presence of representatives of the three leading European foundrymen's associations, and the reading of exchange papers from the Institution of British Foundrymen, the Association Technique de Fonderie de Liege, and the Association Technique de Fonderie de Francaise, the meeting forecasted for the future a great international gathering of the foundrymen of the world. International exchange of foundry knowledge and co-operation of foundrymen of the world to promote the interest of the industry was the keynote at this meeting and at the meeting of the Institution of British Foundrymen which were held almost simultaneously.

Molding sand was given great prominence because of the work of the joint committee on molding sand research of the American Foundrymen's Association and the National Research Council. The regularly scheduled session on Thursday on this subject was of such interest that a second session had to be arranged to give time for completion of discussion. Non-ferrous metals were emphasized more than in the past by having, with the Institute of Metals division of the A. I. M. E. four ses-

sions; two A. I. M. E. sessions, a joint A. F. A. and A. I. M. E. session and one A. F. A. session. For the first time in the history of the association, aluminum and aluminum alloys were given a distinct place on the schedule, the joint meeting being devoted to these subjects.

In all 46 papers and 10 committee reports were presented at the nine A. F. A. technical sessions. A gratifying feature of these meetings was the extensive discussion of the papers by members attending. In addition to the eleven technical sessions, the convention opened on Monday afternoon with a meeting at which the foundrymen were welcomed to Rochester by city officials and the convention closed on Friday with a strictly business session.

Regret by all was felt at the absence of President Bean who was kept away by serious illness.

Joint Opening Session

Monday, June 5, 2 p. m. Assembly Hall

Reverting to the custom of past years, the convention was formally opened by a joint meeting of the American Foundrymen's Association and the Institute of Metals division of the American Institute of Mining and Metallurgical Engineers in Assembly Hall at Exposition Park. In the absence of President Bean, C. R. Messinger, vice president of American Foundrymen's Association, and W. B. Price, Chairman, Institute of Metals division of the A. I. M. E., jointly presided.

The addresses of welcome were made by Mr. Flannery, on behalf of Mayor C. D. Van Zandt of Rochester, and by James E. Gleason, president of the Rochester Chamber of Commerce. Response was made on behalf of the two associations by C. R. Messinger, after which Vice President Messinger reviewed the activities of the A. F. A. during the past year and a half. Secretary C. E. Hoyt of the American Foundrymen's Association then made some general announcements concerning the week's program, and V. E. Kreuter, Chairman of the Rochester entertainment committee, outlined the plans that had been made to care for the pleasure and comfort of the visiting foundrymen.

Vice President Messinger announced the closing of the polls and appointed as tellers R. F. Harrington, chairman, W. J. Brant and J. F. Harper. The appointment of the judges for the Obermayer Award contest was also announced, the committee personnel being, Benj. D. Fuller, chairman, Pat Dwyer and Fred L. Wolf.

Following the appointment of these committees the following message from President Bean was read by W. B. Price:

"While bodily ill makes impossible my physical presence I shall be with you in spirit in the opening session this afternoon and in all the activities of the week. The period since our last convention has been one of many vicissitudes for most of those in the foundry industry but I am looking with much hope to the year ahead."

After the reading of this message, R. A. Bull, past president of the A. F. A., moved that the meeting authorize the transmission of a telegraphic message to President Bean, deploring his illness and inability to be present, and acknowledging the receipt of his message to the Association. The motion was unanimously approved and Chairman Messinger appointed R. A. Bull, past president of the A. F. A., V. E. Minich, member of the A. F. A. Board of Directors, and W. B. Price, chairman of the Institute of Metals Division to draft the message. The telegram which was sent at once read as follows:

W. R. Bean: Your message read at opening session and much appreciated. The Association by vote authorized us as committee to acknowledge your greetings and express the deepest regret at your absence. Also our earnest desire that you may experience a speedy and permanent recovery. Cheer and good luck.

International Session

Tuesday, June 6, 9:30 a. m. Assembly Hall

A. O. Backert, Past President, the American Foundrymen's Association, in the chair.

Before the beginning of the reading of the regularly scheduled papers for this session, the chairman made a short statement regarding the arrangement for an annual exchange

of technical papers between the A. F. A. and the Institution of British Foundrymen, the Association Technique de Fonderie de Francaise and Association Technique de Fonderie de Liege, after which he introduced the representatives of these associations who were received with great applause.

F. J. Cook, Rudge-Littley Ltd. Birmingham, England, Past President of the Institution of British Foundrymen, on being introduced, read the folowing cablegram from Oliver Stubbs, President of the Institution of British Foundrymen:

"Convey the heartiest greetings to President and members, with all good wishes for a successful convention and inspiration from International Foundrymen's Congress in the near future."

Marcel Remy, Herstal, Belgium, member of both the Association Technique de Fonderie de Liege and Association Technique de Fonderie de Francaise, the foundrymen's association of Belgium and France, respectively, presented letters of greetings on behalf of these two associations, which were read by Raymond Gailly of Charleville, France. These letters are as follows:

June 6, 1922.

American Foundrymens' Association,

Rochester, N. Y.

Gentlemen: On behalf of the Foundry Technical Association of Belgium we have a most pleasant duty before us: that of availing ourselves of the opportunity offered by our trip to America to express to you the deep sympathy and gratitude of your Belgian colleagues.

First, gratitude: The Belgium of 1914-1918 will never forget what she owes to America, whose sentiments were so necessary a moral support during those dreadful times, and whose magnificent aid enabled her to bind her wounds and await the day when the enemy hordes would leave her free again. We shall not forget either the influence of your brave regiments, who played such an important part in the Allied drive, liberating the territory of our great French friends and ours; and, what is more, marking the victory of right and the defeat of an excessive imperialism, whose first victims we were.

Second, sympathy: We are drawn to you by an irresistible sympathy, born before the war, strengthened by the latter, and made up of as much friendship as of admiration for the gigantic work which your extraordinary activity enables you to carry out in every field of endeavor.

We would also like, my dear colleagues, to tell you of the firm resolve of our race to conquer the obstacles of the present hour. Our work, our energy, our intelligence, within the limits of their development—all are at the service of what still remains to be done for the reconstruction of our country. It is in part the sincerity of this feeling that has induced the Liege Foundry Technical Association to make itself known to its great sister organization, the American Foundrymen's Association.

Our F. T. A. exercises its influence within a limited field. It tries to conquer the numerous difficulties of our interesting industry, and to help restore and completely develop our foundries.

The F. T. A. of Liege follows your work with more and more interest. Your fortunate initiatives, your practical conclusions, reveal to us a model association which we shall try to emulate in so far as possible. Our F. T. A. wishes to ask you to accept from this day on its modest co-operation and to set up across the ocean a link binding us together, mutually recalling our similar activities in the same direction. We are already in close touch with our sympathetic French colleagues, and in the course of this month we shall establish at Birmingham a contact with our English friends. To re-establish an allied front in the foundry field cannot bring anything but victory in the struggle undertaken by science and the foundry technique.

The F. T. A. of Liege renews the assurance of its brotherly feeling and sincere good fellowship and conveys to your Association its best wishes for your prosperity.

Three cheers for the A. F. A!

The second letter read was as follows:

"Gentlemen: The Foundry Technical Association of France, to which I have the honor to belong, unable to send a delegate to represent it here, asked me when I was coming through Paris to convey verbally to you the expression of its friendly feeling, and to state its regret at not being able to be with you today, on account of the great distance.

"The F. T. A. was obliged to interrupt its activities during the terrible war which absorbed, at the front and in other work, the greater part of the energy of its members, for the defense of the rights of every nation. It is now in course of complete reorganization and it is certain that very shortly it will be in a position to participate more and more effectively in works in common, as regards all that relates to the smelter's art.

"The F. T. A. has presented to you a report which Mr. Backert, one of your Presidents, asked for in 1919; it deals particularly with the systematic devastation of foundries which were located in the occupied zones.

"It is to be hoped that all these industries, the reconstitution of which is already in a very advanced stage, may be definitely put in complete working order very soon, so that the prosperity of France, as far as the smelter's art is concerned, may not suffer in any way.

"Gentlemen, it is my privilege to convey to you, in the name of the F. T. A., its best wishes for the prosperity of the American Foundrymen's Association and its sincere desire to co-operate in a friendly and useful manner for the greater good of our respective countries."

Chairman Backert then read a letter from Jean Carles, L'Ingenieur Delegue, Association Technique de Fonderie de Francaise, which is given below:

C. E. Hoyt, Secretary,
American Foundrymen's Association.
Dear Mr. Hoyt:

In a previous letter, Mr. E. Ronceray stated that probably Monsieur Prosper Aubie, director of the Usines de Chamberg

de l'Aluminum Francais, would represent the Association Technique Francaise at your convention at Rochester.

Unfortunately Monsieur Aubie in a recent letter advises that his visit must be postponed until the month of October. We regret very much the circumstances by which the French association will not be officially represented at your convention.

We offer our best wishes for the success of your convention and we are convinced that the discussion of the papers presented will arouse a technical and practical interest in the foundry art.

We beg to extend, Monsieur, our best wishes.

L'Ingenieur Delegue
J. CARLES.

After the representatives had been introduced and the greetings read a motion was made and unanimously passed that the chairman appoint a committee of three to draft messages of good greetings and of good fellowship to the European foundrymen's associations. The chairman then appointed on this committee C. R. Messinger, Major R. A. Bull and G. H. Clamer.

The following program of papers was then given:

"Annealing of Gray Iron," by J. F. Harper and R. S. McPherron, Allis Chalmers Co., Milwaukee, Wis.

"European versus American Molding Machine Practice," by E. Ronceray, President, Societe Anonyme des Etablissements Ph. Bonvillian, and E. Ronceray, Paris. Read by title.

"Making Typewriter Frames in a Belgian Foundry," by Joseph Leonard, President, Association Technique de Fonderie de Liege, Herstal, Belgium. Annual Exchange paper. Read by title.

"Destruction and Reconstruction of French Foundries," a Memoir submitted by the Association Technique de Fonderie de France. Annual Exchange paper. Read by Raymond Gailly, Charlesville, France.

"Cupola Melting Tests with Mixtures Changing During Run," by Richard Moldenke, Watchung, N. J.

"American vs. British Cast Iron," by F. J. Cook, Rudge-Littley, Ltd., Birmingham. Annual Exchange Paper of the Institution of British Foundrymen.

The papers by Messrs. Ronceray and Leonard in the absence of the authors were read by title. During the discussion of the paper by F. J. Cook, Walter Wood of R. D. Wood and Co. of Philadelphia, read a statement regarding the desirability of resuming work on international foundry standards.

After this statement was read Dr. Richard Moldenke, presented the resolution given below, which was unanimously adopted.*

RESOLVED: That the American Foundrymen' Association will welcome the resumption of deliberations looking toward international agreement upon methods of foundry procedure and specifications;

That the American Foundrymen's Association deems an early agreement on an international test bar. and the purchase and use of pig iron by its analysis only, essential in the interest of intensified export trade. The A. F. A. is prepared to co-operate with Foundrymen's and engineering societies of other countries to this end.

At the close of this session a rising vote of thanks was given to the foreign visitors.

Steel Session

Tuesday, June 6, 2 p. m., Assembly Hall.

C. S. Koch, past president, American Foundrymen's Association in the chair.

The following papers and reports were read and discussed:

"Side Blow Converters for Steel Foundries," by T. Levoz, Association Technique de Fonderie de Francaise, one of five exchange papers from the French foundrymen's association. Read by title.

*For Board action refer to page 34.

"Tests with Cerium as a Deoxidizer and Desulphurizer in Red Brass, Cast Iron and Converter Steel," by L. W. Spring, The Crane Co., Chicago. Read by title.

"The Preparation of Steel Foundry Sands," by S. H. Cleland, The National Engineering Co., Chicago, Ill.

Report of the A. F. A. Committee on Specifications for Steel Castings.

Report of A. F. A. representative on Joint Committee for Investigation of Phosphorus and Sulphur in Steel.

"When and Where the Foundry should use Electric Heat," by E. F. Collins, General Electric Co., Schenectady, N. Y.

"Accurate Control of Analyses in Acid Electric Steel Furnaces," by A. C. Jones, Electric Steel Co., Chicago. In the absence of the author this paper was read by R. A. Bull.

A. F. A. Brass Foundry Session

Tuesday, June 6, 2 p. m., Municipal Museum Building.

Jesse L. Jones, Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa., in the chair. The following addresses were read and discussed:

"Technical Control of McCook Field Foundry," by E. H. Dix, Jr., McCook Field, Dayton, Ohio.

"Selection of Fuels and Furnaces for Melting Copper and Brass Alloys," by T. H. A. Eastick.* Presented by title.

"An Investigation of 'Segregation' with a view to Preventing its Occurrence in Castings made of High-Lead Bronze," by R. E. Lee and F. B. Trace, Allegheny College, Meadville, Pa.

"Nickel, its Metallurgy, its Properties and Uses," by W. M. Corse, Secretary, Institute of Metals division of A. I. M. E.

"Brass Forgings," by C. G. Heiby, Mueller Metals Co., Port Huron, Michigan.

"Two-part Castings Made in Three-part Molds," by W. H. Parry, Brooklyn, N. Y. Presented by title.

The address by W. M. Corse was accompanied by the showing of several reels of moving pictures on the manufacture of the metal nickel.

*Deceased

JOINT MEETING ALUMINUM AND ALUMINUM ALLOYS SESSION

Wednesday, June 7, 9:30 p. m., Assembly Hall.

R. J. Anderson, Bureau of Mines Experiment Station, Pittsburgh, Pa., acted as chairman. The following papers were read and discussed:

"Use of Secondary Aluminum Ingot in Foundry Practice," by W. M. Weil, National Smelting Co., Cleveland, Ohio.

"Aluminum and Aluminum Alloy Melting Furnaces," by R. J. Anderson, Bureau of Mines, Pittsburgh, Pa.

"Melting Aluminum for Rolling into Sheets," by J. A. Lange, Western Springs, Illinois.

"Cracks in Aluminum-Alloy Castings," by R. J. Anderson, Bureau of Mines, Pittsburgh, Pa.

"The Effect of Impurities on the Oxidation and Swelling of Zinc-Aluminum Alloys," by W. M. Pierce and H. E. Brauer.

H. B. Swan acted as chairman during the reading of the papers by R. J. Anderson.

GENERAL AND GRAY IRON SESSION.

Wednesday, June 7, 9:30 a. m., Assembly Hall, Lower Floor.

G. H. Clamer, member of the Board of Directors of the American Foundrymen's Association presided as chairman. The following paper and committee reports were presented and discussed.

"A Study of the Weight of Iron Castings," by J. D. Wise, University of Illinois, Urbana, Illinois. Read by title.

"Electrically Heated Metal Patterns," by C. A. Cremer, Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa.

"Flask Equipment for Molding Machines," by Arnold Lenz, Saginaw Products Co., Saginaw, Michigan. Read by title.

"Design of Geared Ladles," by A. W. Gregg, Whiting Corp., Harvey, Illinois. Read by title.

"Investigations Relative to Insulated Core Oven Design and Performance," by C. F. Mayer, Ohio Body and Blower Co., Cleveland, Ohio.

"Technical School Foundries," by J. D. Hoffman and R. E. Wendt, Purdue University, Lafayette, Indiana.

Report of A. F. A. sub-committee on Specifications for Cast Iron Wheels.

"Memorial on Corrosion of Cast Iron," by H. Y. Carson, American Cast Iron Pipe Co., Birmingham, Alabama.

Report of A. F. A. Committee on Specifications for Gray Iron Castings.

Report of Committee on Industrial Education and Training of Apprentices.

Report of Committee on Foundry Costs.

During the discussion of the Memorial on the Corrosion of Cast Iron, the following motion was made, seconded and approved by the meeting:

"Moved, That it is the sense of this meeting that the aims and purposes of the Memorial on the Corrosion of Cast Iron by H. Y. Carson be approved and that the matter be referred to the Board of Directors of the A. F. A. for action and appointment of a committee to investigate the subject of corrosion of metals."

After the reading of the report of the Committee on Specifications for Cast Iron, a motion was made and approved that the report be received and that the recommendations be referred to the Board of Directors for suitable action. The report of this committee included recommendations for changes in the A. S. T. M. specifications for pig iron, specifications for high test cast iron, and specifications for testing by-product coke.

Steel Session

Wednesday, June 7, 8:30 a. m., Municipal Museum Building.

A. H. Jameson, Bayonne Steel Casting Co., Bayonne, N. J., presided as chairman. The following papers were presented:

"A New Electric Furnace", by R. Sylvany, Association Technique de Fonderie de Francaise, Abstract read.

"Progress in Open Hearth Process," by Willis McKee, of Arthur G. McKee and Co., Cleveland, Ohio.

Report of Committee on Steel Foundry Standards.

"A Managerial Study of Oxy-Acetylene Cutting and Welding in Foundries," by G. O. Carter, The Linde Air Products Co., New York.

"Electric Cranes in Foundry Service," by A. H. McDougall, Whiting Corporation, Harvey, Illinois. Abstract read.

After discussing the report of the committee on steel foundry standards it was moved that the recommendations of the report be approved. This motion was carried.

Industrial Relations Session

Wednesday, June 7, 2:00 p. m., Assembly Hall.

Dr. Clifford B. Connelley, Department of Labor and Industry, State of Pennsylvania, Harrisburg, Pa., presided as chairman. The following papers and report were read:

Report of A. F. A. Committee on Safety, Sanitation and Fire Prevention, by Benjamin D. Fuller, Chairman, Defiance Paper Co., Niagara Falls, N. Y.

"Cycles of Depression and Their Prevention," by Ernest F. DuBrul, General Manager, National Machine Tool Builders Association, Cincinnati, Ohio.

"Prevention of Waste in Industry," by L. W. Wallace, Executive Secretary, Federated American Engineering Societies, Washington, D. C. Read by title.

"Time Study and Job Analysis in The Foundry," by A. J. Kramer, Deering Works, International Harvester Co., Chicago.

"Eye Protection and Safe Clothing in the Foundry," by Buell W. Nutt, The Safety Equipment Service Co., Cleveland.

Molding Sand Research Session

Thursday, June 8, 9:30 a. m., Assembly Hall.

R. A. Bull, Past President, the American Foundrymen's Association and Chairman of the Joint Committee on Molding Sand Research, presided. The following reports and paper were read and discussed:

Report of Joint Committee on Molding Sand Research of the American Foundrymen's Association and the National Research Council, presented by R. A. Bull, chairman.

Report of Sub-committee on Geological Survey presented by H. Ries, chairman, Cornell University, Ithaca, New York.

Report of Sub-committee on Conservation and Reclamation of Foundry Sand, presented by F. L. Wolf, chairman, Ohio Brass Co., Mansfield, Ohio.

Report of Sub-committee on Standard Tests, presented by H. B. Hanley, chairman, New London Ship and Engine Co., Groton, Conn.

"Establishing a Method of Testing for Green Bonded Strength" by R. J. Doty, Sivyer Steel Casting Co., Milwaukee.

The session adjourned until Friday morning.

Molding Sand Session

Friday, June 9, 9:30 a. m., Assembly Hall Building.

R. A. Bull, Past President, American Foundrymen's Association, presided during the first part of the session, and on his departure F. L. Wolf, Ohio Brass Co., Mansfield, Ohio, took the chair. This session was arranged to provide for the reading of certain papers which had been scheduled for the Thursday morning session. The papers read and discussed follow:

"A Study of the Change of Grain Size of Silica Sand on Constant Addition of Clay," by R. J. Doty, Sivyer Steel Casting Co.

"Significance of Screen Test of Molding Sand," by H. A. Schwartz, National Malleable Casting Co., Cleveland, Ohio, presented in abstract by H. B. Hanley, New London Ship and Engine Co., Groton, Conn.

"Report on Sand Reclamation Investigation of the American Steel Foundries," read in abstract by R. E. Kennedy, Urbana, Illinois.

Malleable Iron Session

Friday, June 9, 9:30 a. m., Assembly Hall.

C. R. Messinger, vice president, American Foundrymen's Association, presided. The following papers and reports were read and discussed:

"The Manufacture and Properties of Refractories for Air Furnaces," by C. E. Bales, Louisville Fire Brick Co., Highland Park, Kentucky.

"The Behavior of Fire Brick in Malleable Furnace Bungs," by H. G. Schurecht, Bureau of Mines, Columbus, O. (By title).

"A European View of the Malleable Problem," by T. Levoz, Association Technique de Fonderie de Francaise. (By title).

"Use of Carbon Dioxide Recorders in Controlling Combustion of Powdered Coal," by D. M. Scott, The T. H. Symington Co., Rochester, N. Y.

"Use of Pulverized Coal for Malleable Foundries," by E. E. Griest, Chicago Railway Equipment Co., Chicago.

Report of Committee on Malleable Castings Specifications. Read by H. W. Highriter, Eastern Malleable Iron Co., Naugatuck, Conn.

"The Relation of Temperature to the Form and Character of Graphite Particles in the Graphitization of White Cast Iron," by E. J. C. Fisher, Atlas Die Casting Co., Worcester, Mass.

"The Influence of Temperature and Composition on the Graphitization of White Cast Iron," by A. E. White and H. E. Gladhill, University of Michigan, Ann Arbor, Michigan.

Business Session

Friday, June 9, noon, Assembly Hall

C. R. Messinger, Vice President American Foundrymen's Association presided. Following the opening remarks by the chairman, Secretary-Treasurer C. E. Hoyt, made a general statement regarding the conditions of the Association and then the following resolutions prepared by the Committee on Resolutions were presented and unanimously adopted:

"Having enjoyed the renowned hospitality of the city of Rochester during the past week and benefited by a notable series of technical sessions provided with valuable papers produced from careful study of the problems of the foundry, and having profited by a complete exhibit of foundry equipment and supplies it is fitting that we express the gratitude which we feel to all those who have so generously labored and donated that this convention might be carried enjoyably,

"Therefore we extend our thanks to the local Rochester Committee for their untiring efforts and attention to every detail;

"To the Rochester Chamber of Commerce for its activity and co-operation in the perfection of general plans;

"To the several prominent citizens of Rochester and to the residents as a whole for their cordial and warm hospitality; and to the local press which has so generously heralded and recorded the activity of the convention;

"To the British, French and Belgian foundry associations for their co-operation in exchanging papers and to Messrs. Cook, Gailly and Remy for their presence as representatives respectively of the three foreign associations which made possible its first notably successful international session in the association's history;

"To the chairman and members of the papers committee, to the authors of the papers and to the chairmen of the various technical sessions whose work made all of the meetings so signal a success;

"And finally to our president, W. R. Bean, whose untiring effort throughout the year has brought an era of progress to our association, during a trying time in industry, and of whose presence at the meetings we unfortunately are deprived of through his illness."

Upon motion of Verne E. Minnich, member of the Board of Directors, W. R. Bean, retiring President, was unanimously elected an honorary member of the American Foundrymen's Association and the Secretary was instructed to inform Mr. Bean of this election.

At this time Secretary Hoyt read the following telegram which had just been received from Mr. Bean:

"I wish through you to acknowledge receipt of the several cordial messages which have come to me this week. Will you, as opportunity offers, extend my sincere appreciation and say that I am resting comfortably and apparently making progress toward a complete recovery."

Chairman Messinger next read messages of greetings transmitted by F. J. Cook, of Rudge-Littley, West Bromwich, England, from the following English societies: Institution of British Foundrymen, the Birmingham Metallurgical Society, the South Staffordshire Iron and Steel Institute, the British Cast Iron Research Association, the Midland Iron Founders' Association and the Malleable Iron Founders' Association.

On the unanimous adoption of a motion that the chair be instructed to appoint a committee to acknowledge and respond to these greetings, a committee was appointed composed of Major R. A. Bull, G. H. Clamer and W. B. Greenlee.

The report of the tellers on being read announced the election of new officers as follows:

President, C. R. Messinger, and Vice President G. H. Clamer. Directors elected to serve for the following three years were C. B. Connelley, C. E. Hoyt, Fred Erb, L. W. Olson and A. B. Root, Jr. After appropriate remarks by the newly elected officers who were present and by L. L. Anthes, Past President of the Association, the meeting adjourned.

Annual Banquet

Wednesday, June 7, 7 p. m., Powers Hotel.

In the absence of President Bean, Vice President Messinger presided and introduced Roland Woodward, Secretary of the Rochester Chamber of Commerce, as toastmaster. F. J. Cook, the visiting representative of the Institution of British Foundrymen, gave an address on the possibilities of co-operation between the two associations after which the chairman introduced the speaker of the evening, Governor Henry J. Allen of Kansas who spoke on the Kansas Industrial Relations Court.

Entertainment Features

The Rochester entertainment committee with the co-operation of the local foundrymen provided a program of entertainment for the visiting foundrymen and their guests that has seldom if ever been surpassed in the history of the Association's conventions. The big event of the week was the boat ride on Thursday afternoon when a trip was made across Lake Ontario to Coburg and return. Facilities for plant visitation and golf were provided for all, special taxicab service was arranged and the local hotel committee took care of visitors who were unable to make hotel arrangements before arriving at Rochester. The visiting ladies were well taken care of by an auto trip around the city with tea at the Oak Hill Country Club and by a recital at Kilbourn Hall.

Transactions

of the

American Foundrymen's Association

Summary of Association Activities

By the President, W. R. Bean

SERIOUS illness just prior to and during the twenty-sixth annual convention of the association, which met in Rochester, N. Y., June 5 to 9, inclusive, precluded the possibility of the usual annual address and this brief statement is at the urgent request of the secretary reluctantly made just before the official transactions go to press.

It is a matter of sincere regret that after almost two years in the office of president of the association, I was unable to be present at the Rochester meeting to participate in the activities of the week.

First of all I wish to express to the vice president of the association, C. R. Messinger, to the secretary, C. E. Hoyt, and to the directors my sincere appreciation of the way in which they stepped into the breach and took over the work which I should have done so that, measured by actual accomplishment of results, my absence was not felt.

Immediately following the Columbus convention in 1920 came the industrial depression which adversely affected all branches of the iron and steel industry, and industry in general, showing no favoritism toward the foundry industry. This brought many and unusual problems to the officers and directors of the association which required both knowledge and foresight to meet and solve. The directors, always ready and loyal, met these responsibilities and it is possible now to look back upon

the elapsed period with a reasonable degree of satisfaction in things actually done.

As a result of the unusual business conditions during both 1921 and 1922, the association was asked to participate through its executive organization in consideration of some of the large problems affecting the interests of its members.

I would mention in particular the request from Secretary Hoover of the department of commerce for co-operation in the matter of statistical data pertaining to foundry products and raw materials, also the opportunity offered by the interstate commerce commission for appearance before that body in advocacy of reduction in freight rates on pig iron and other raw materials.

Our association being fundamentally a technical body and not a trade or business organization the scope of our participation in response to the invitations received was limited, but we were able to co-operate and did so in so far as it was felt the purposes of our organization could be served.

The subject of award funds and awards to be made from these funds received a great deal of consideration on the part of the awards committee and the officers of the association with the result that many of the intricate details were brought into shape for final action on the part of the incoming officers and directors. There is much to be hoped for in the way of stimulation to a closer study of some of the fundamentals of the industry in its different branches through the awards which are to be made from the funds so generously donated by members of the association, of long standing, who have so deeply at heart the best interests of the association and the industry which it represents.

With a broadening of activities for the benefit of the industry and members, closer co-operation with allied associations, promotion of international relations with foreign foundrymen's associations, and the initiation of research projects which have resulted during this time, it is felt that the association now is in a position to make even greater strides forward.

With the growth of the association and its increased activ-

ities a need was felt for a better and more regular means of communication with the members between conventions. To meet this need a publication known as the "Bulletin of the American Foundrymen's Association" was started, the initial number appearing in September, 1921. The purpose of the bulletin is to keep members informed of all the association activities, report the progress of committees, and furnish abstracts of current foundry literature. As the purpose and aims of the association are largely reflected in its committee activities it is felt that the bulletin by keeping the members more fully informed will enable them to co-operate fully and thereby increase the effectiveness of the committees. Six numbers of the bulletin were issued up to the time of the Rochester convention, the plan now being to issue a number bi-monthly. It is expected that the abstracts of current foundry literature will provide the members with a complete file of references in the foundry subjects, and as the numbers of the bulletins accumulate the abstracts will prove of more and more assistance to the man seeking sources of knowledge.

Index to Transactions Issued

The index to the bound volume of *Transactions* of the association, which while prepared previous to the twenty-fifth convention, was not sent to the printer and distributed to the members till the spring of 1921. This index of 191 pages with references to the papers of transactions, Volumes IX to XXIX, makes available ready references to a vast amount of the best literature on foundry topics that has been printed in this country.

The American Foundrymen's association recently has taken the lead among the technical societies of the country in establishing an intelligent exchange of technical information with similar foreign associations by making arrangements for an annual exchange of papers with the leading foundrymen's associations of Europe. Beginning with a formal agreement completed in 1920 between the American Foundrymen's Association and the Institute of British Foundrymen, the arrangement has now been en-

larged to include the Association Technique de Fonderie de Leige, and the Association Technique de Fonderie de Francaise, respectively the associations of Belgium and France. The first paper under this exchange agreement was given by G. K. Elliott of the Lunkenheimer Co., Cincinnati, before the 1920 meeting of the British institution, while at the Rochester convention papers were presented by representatives of all three of the European associations. Enrique Touceda presented the second of the American papers at the 1921 meeting of the Institution of British Foundrymen and another American paper was presented at the 1922 French association meeting.

Without doubt the most important undertaking of the association in recent years was in the organization in co-operation with the division of engineering, National Research Council, of a joint committee for investigation of molding sand problems. This committee composed of some 40 members includes in its personnel, representatives from the United States bureau of mines, United States bureau of standards, United States geological survey, and the American Society for Testing Materials. Much progress has been made and a foundation laid for the development of sand testing methods, complete survey of foundry sands and an accumulation of research data relating to many of the foundry problems on the conservation and reclamation of molding sand.

Work of Committees Expands

Committees have been very active as evidenced by the results of the committee work presented at the twenty-sixth annual convention. The list of technical committees reporting was greater than for any previous year. The American Foundrymen's association and the National Founders association Safety and Sanitation code has been adopted with but few slight changes by the American Engineering Standards committee as a national standard. The American Foundrymen's association committee on specifications for malleable cast iron, steel castings, and gray iron castings, with their representatives working in

conjunction with the American Society for Testing Materials reported that revised specifications were being formulated to take care of the defects which appeared in the old standards. The American Foundrymen's association representative on the American Society for Testing Materials committee on cast iron car wheels reported the completion and tentative adoption of a set of standard specifications.

During the past few months active steps have been taken looking toward closer co-operation with the American Society for Testing Materials. A joint committee of the two societies has reviewed the present relations of the two bodies, and made recommendations which were approved by the two societies. The recommendations provided for representation of the American Foundrymen's association on all those American Society for Testing Materials committees whose work is of interest to the foundrymen. Committees on which the American Foundrymen's association is not represented at the present time and on which it is desirable to have representatives are: A-4, heat treatment of iron and steel; B-2, nonferrous metals; C-8, refractories; D-6, coke; E-4, metallography. American Foundrymen's association representatives have been appointed on these committees and are acting as chairmen of similar recently appointed American Foundrymen's association committees.

Need of Cost System for Small Foundries

Though the association has in the past developed and approved a standard cost system and recommended its use, it was felt that while applicable to plants having well organized cost departments, it would not fill the needs of the smaller gray iron foundries which had only simple bookkeeping departments. With this in mind the committee on foundry costs developed a set of forms which can be used by the smaller foundries in obtaining work cost data. The same forms can, however, be expanded and used by the firms with a better organized cost department.

The committee on apprentice training desiring to get a definite idea as to the interest of the members on the question of training apprentices sent out a questionnaire to all members firms. As only about 3 per cent of the questionnaires were

returned it was felt that the average foundryman takes very little interest in the subject. However from the many replies received from various sources the consensus of opinion seems to be that there is a vital need for more and better training of men to fill the demand for foremen and supervisors.

Annual Report of the Board of Directors

To the Members of the American Foundrymen's Association, Inc.:

The by-laws provide that the officers and directors elected by mail ballot of the members shall take office at the time of the first annual meeting of the board following their election.

The report submitted herewith covers all the meetings of the board and committees thereof elected in October, 1920. Their term of office beginning Dec. 6, 1920, carried through to Oct. 3, 1922, due to the fact that no convention or election was held during the calendar year 1921, as a result of the decision to return to the practice of holding spring meetings.

Four meetings of the board, two meetings of the executive committee and two meetings of the committee on convention and exhibits were held during this period. To avoid the expense of meetings many questions were decided by letter ballot, including the decision to hold the 1922 convention at Rochester in June after it was found impracticable to meet in Cleveland on the dates the board had selected.

A brief summary of the minutes of these meetings is given, followed by the full minutes of each meeting of the board and its committees, the report of the manager of exhibits and the auditor's report from the department of exhibits.

Dec. 7, 1920. The first meeting of the board was held at Rochester with 16 members present, one absent. The board organized by electing a secretary-treasurer, a manager of exhibits and an executive committee of the board.

Feb. 8, 1921. A meeting of the executive committee was held in New York. At this meeting it was decided to cooperate with the National Research council in organizing a joint committee on molding sand research. It was voted to

make available for this work the Pangborn research fund of $2500, contributed by Thomas W. and John C. Pangborn.

March 30. A meeting of the committee on convention and exhibits was held in Cleveland to consider plans for holding a 1921 convention. The committee voted to recommend to the board of directors that a convention without an exhibit be held in New York City in October or November.

May 28. A meeting of the executive committee was held in New York. The recommendations of the committee on convention and exhibits were carefully considered, following which it was voted to hold a convention with exhibits in the spring of 1922 at a place to be selected by the convention and exhibits committee.

A resolution was adopted extending the co-operation of the association with the secretary of the United States department of commerce in his efforts to extend the field of usefulness of the department to commerce and industry.

Dec. 6. A meeting of the convention and exhibits committee was held in Cleveland. The manager submitted a detailed report of the plans for an exhibit to be held in the new auditorium in Cleveland in conjunction with an annual convention, which it had been decided by mail ballot to hold during the week of April 24. The manager reported that a question had arisen as to the possibility of securing the auditorium and was instructed not to proceed any further until a lease was obtained and in the meantime to investigate conditions in other cities.

On the same day the annual meeting of the board of directors was held in Cleveland. Reports of officers and committees were received. It was voted that all officers and assistants elected by the board Dec. 6, 1920, be continued in office until their successors were elected by a new board which will be elected by letter ballot in the spring of 1922 as provided by the by-laws.

Resolutions were adopted on the deaths of past Presidents Joseph Sidney Seaman, 1900, and William Adrian Jones, 1901.

A special committee recommended revisions to articles 9 and 10 of the by-laws on the nomination and election of offi-

cers and directors and article 12 on the date of the annual board meeting. The recommendations were approved and ordered submitted to the members for ratification by mail ballot, and if ratified, to become effective immediately after adjournment of the next annual meeting of the association.

A contribution of $1000 to the research fund by Herbert S. Simpson was announced. It was unanimously moved that a vote of thanks be extended to Mr. Simpson for his most generous contribution.

June 6, 1922. A meeting of the board was held at Rochester following the annual dinner of officers, directors and honorary members. Mr. Frederick J. Cook, the representative of the Institute of British Foundrymen to the Rochester convention of the American Foundrymen's association was present as a special guest. It was voted to recommend to the association that retiring President W. R. Bean be elected an honorary member. The report of the committee to confer with the American Society for Testing Materials on a plan of cooperation between the two societies was received and approved. A resolution presented at the international session of the association that day looking toward an agreement on an international test bar and the purchase and use of pig iron by analysis only, was received and the president instructed to appoint a committee of three directors to take these questions under advisement and make recommendations to the board.

In accordance with the provisions of the by-laws, an annual meeting of the board was called for Tuesday, Aug. 29. This date was not found to be convenient and by common consent of all the members the annual meeting was adjourned until Oct. 3.

Oct. 3, 1922. The annual meeting of the board of directors of the American Foundrymen's association was held in Chicago. Vice President Messinger presiding, announced the death of Director and past President J. P. Pero at his home in Indian Orchard, Sept. 23, and appointed a committee to prepare resolutions to be spread upon the records and to be sent to the members of Mr. Pero's family. Reports of officers and

committee chairmen were received. Report of the secretary-treasurer showed a cash balance of $1323.90 in the technical department with accounts receivable of $3806, which included $2000 previously voted to be transferred from the department of exhibits, which transfer had not been made. The secretary stated that the fiscal year of the association ended Dec. 31, at which time the books would be closed and audited.

The report of the manager of exhibits for the Rochester exhibit showed a total cash balance on Aug. 31, at which time the books of the department were audited, of $7436.17.

The reports and the audit for the department of exhibits were received and referred to the finance committee, who later made the following recommendations:

First: That the sum of $2000 previously set aside from the earnings of the Columbus exhibit be transferred to the technical funds.

Second: That the sum of $1000 be transferred to the technical department and $250 contributed to the Institute of Metals Division of the American Institute of Mining Engineers from the earnings of the exhibit department for the past year.

The recommendations were approved.

Resolutions on the death of Henry A. Carpenter were read and copies ordered spread on the records and sent to the family of the deceased.

The election of retiring President W. R. Bean to honorary membership was confirmed.

The report of the judges of election who canvassed the votes for officers and directors at the election in June was read and confirmed, the men elected to take office immediately after adjournment of this meeting, which was to be followed by a meeting of the new board.

The minutes of all the board and executive meetings follow. A more detailed report of the activities of the technical department will be found in the annual report of the secretary-treasurer.

Respectfully submitted,

C. E. Hoyt, *Secretary*.

Minutes of Meetings of Board of Directors

MEETING OF THE BOARD OF DIRECTORS OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION, AT THE GENESSEE VALLEY CLUB, ROCHESTER, N. Y., TUESDAY, DEC. 7, 1920.

The first meeting of the board of directors elected by letter ballot at the annual convention in Columbus, O., the week of Oct. 4, 1920, convened immediately after the adjournment of the annual meeting of the retiring board held at the same date and place.

The following were present: H. R. Atwater, A. O. Backert, W. R. Bean, R. A. Bull, G. H. Clamer, Fred Erb, B. D. Fuller, Alfred E. Howell, C. E. Hoyt, S. T. Johnston, W. A. Janssen, C. S. Koch, C. R. Messinger, V. E. Minich, L. W. Mueller and J. P. Pero.

A wire was received from S. B. Chadsey, the only absent director, advising that illness prevented his attendance. There were also present H. A. Carpenter and A. B. Root Jr., whose terms of office as director had expired with the adjournment of the old board.

President Bean in the chair.

Mr. Bull moved that the election of W. R. Bean as president, and C. R. Messinger as vice president, by letter ballot of the members, be confirmed. Mr. Howell seconded the motion which was unanimously carried.

The chair announced as the first order of business the election of a secretary.

Mr. Backert moved that the offices of secretary and treasurer be combined for the ensuing year, as provided for in Section 1, Article 3, of the by-laws. Mr. Bull seconded the motion which was carried.

Mr. Backert nominated C. E. Hoyt, of Chicago, for the office of secretary-treasurer. Mr. Bull seconded the nomination and moved that the nominations be closed. Motion carried. Mr. Bull moved that as there was only one nomination, Mr. Koch be instructed to cast the unanimous ballot of the directors for C. E. Hoyt as secretary-treasurer. The motion was seconded by Mr. Messinger and carried. Mr. Koch formally cast the ballot as instructed, whereupon the chair announced that C. E. Hoyt had been duly elected secretary-treasurer of the association for the ensuing year.

Mr. Backert moved that Mr. Hoyt's salary as secretary-treasurer of the American Foundrymen's association be $2400 per year, payable monthly out of the funds of the technical department. Motion seconded by Mr. Bull and carried.

The chair announced that the next order of business would be the election of a manager of exhibits. C. E. Hoyt was nominated as manager of exhibits, and there being no further nominations Mr. Johnston moved that C. E. Hoyt be declared elected as manager of exhibits. Motion was seconded by Mr. Messinger and carried, whereupon the chair announced that Mr. Hoyt had been duly elected as manager of exhibits for the ensuing year.

Mr. Howell moved that the salary of Mr. Hoyt as manager of exhibits be $7600 per year, payable monthly out of the funds of the department of exhibits. Motion seconded by Mr. Janssen and carried.

Mr. Johnston moved that E. L. Shaner be retained as secretary of the papers committee at a salary of $100 per month. Mr. Janssen seconded the motion which was carried.

The chair announced that the next order of business would be the election of four directors who, together with the president, vice president and secretary-treasurer, would constitute the executive committee. Mr. Messinger moved that the chair appoint a committee of three to nominate four directors for the executive committee. The motion was duly seconded and carried, whereupon the chair named R. A. Bull, G. H. Clamer, Alfred E. Howell.

The chair announced that the next order of business would be the election of four association members, not officers, directors or past presidents, who, together with the last three living past presidents, would constitute the 1921 nominating committee. J. P. Pero, H. R. Atwater and G. H. Clamer were appointed to make a selection of names to be presented to the board for election as members of the nominating committee, whereupon the men named retired to confer.

Mr. Howell, reporting for the committee named to nominate four directors for the executive committee, offered the names of C. S. Koch, A. O. Backert, G. H. Clamer and V. E. Minich, and moved their election. The motion was duly seconded and carried, whereupon the chair announced that the four men just elected, together with the officers of the association, would constitute the executive committee for the ensuing year, with power to act for the directors in the intervals between board meetings.

Mr. Pero, reporting for the committee to nominate members for the nominating committee, offered the names of John Sherwin, of the Chicago Hardware Co., North Chicago, Ill.; W. H. Bassett, of the American Brass Co., Waterbury, Conn.; G. R. Kittle, of the Ohio Malleable Co., Columbus, O., and A. I. Findley, of *The Iron Age,* New York, and moved their election. Mr. Minich seconded the motion, which was carried, whereupon the chair announced that the four members just elected, together with Past Presidents B. D. Fuller, A. O. Backert and C. S. Koch, would constitute the nominating committee for 1921, with Mr. Fuller, senior past president, as chairman.

Mr. Koch offered the following resolution and moved its adoption:

RESOLVED: That W. R. Bean as president, and C. E. Hoyt as secretary-treasurer, are hereby authorized to sign checks and draw against funds deposited in the Harris Trust & Savings bank, and the Standard Trust & Savings bank, of Chicago, and the Central National Bank Savings & Trust Co., of Cleveland, in the name of the American Foundrymen's association.

Motion seconded by Mr. Messinger and carried.

Mr. Minich moved that the president and secretary be authorized to establish a special convention fund of such an amount as is deemed necessary to take care of the payroll and necessary expenses during the convention and exhibit period, and further that they be authorized to provide a petty cash fund of $200 to take care of small items of expense, said fund to be reconciled at the end of each month with full statement of expenditures. Motion seconded by Mr. Janssen and carried.

Mr. Atwater moved that the president and secretary be authorized to engage the services and fix the salaries of necessary assistants, stenographers and clerical help. Motion seconded by Mr. Pero and carried.

Mr. Johnston moved that the customary $15 per diem, railroad fares, and other necessary traveling expenses, be paid to directors and members of the executive and exhibit committes in attendance at all board meetings and committee meetings, except meetings held during annual convention week. Motion seconded by Mr. Pero and carried.

Mr. Pero moved that railroad fares and necessary traveling expenses of members of standing committees be paid by the association, when in attendance on regularly called committee meetings. Motion seconded by Mr. Johnston and carried.

It was duly moved and seconded that from Jan. 1 to July 1, 1921, newly elected members should be required to pay the entrance fee of $10 and annual dues of $12, making them in good standing until Dec. 31, 1921, and should receive without extra cost copy of bound volume of *Transactions* No. 29, covering the 1920 convention, and copies of all other publications issued by the association between Jan. 1 and July 1, 1921. Motion prevailed.

It was duly moved and seconded that all members elected after July 1, whose applications are received before or during convention week, should be required to pay the entrance fee of $10 and annual dues of $6, making them members in good standing to Dec. 31, 1921. They should not, however, receive gratis, copy of bound volume of *Transactions*, but will be entitled to all preprints and all publications published after date of their election. Motion prevailed.

It was duly moved and carried that all members whose applications are received after convention, at the home office of the association should, upon payment of entrance fee of $10 and annual dues of $12, be made members in good standing to Dec. 31, 1922. Motion prevailed.

It was duly moved and seconded that the sale price of bound volume of *Transactions* No. 29, to nonmembers of the association should be $6, and that for libraries and extra copies to members in good standing a 20 per cent discount from this price should be allowed. Motion prevailed.

The secretary reported on invitations received from different cities who desired to entertain the 1921 convention and exhibit. Mr. Erb personally presented the invitation from Detroit, supplementing his invitation on behalf of the foundrymen with invitations from the mayor and the Detroit convention and tourists' bureau. On motion duly seconded all invitations were referred to the committee on convention and exhibits with power to act.

The secretary read a letter from W. E. Skinner, secretary of the National Dairy association, on the subject of proper building accommodations for conventions and exhibits, requesting that the directors appoint a committee to confer with the committee appointed by the directors of the dairy association to consider ways and means of securing better accommodations.

It was duly moved and seconded that the officers of the association and two directors to be appointed by the president, constitute a committee to confer with the committee of the National Dairy association, whereupon the chair appointed for this committee A. O. Backert and S. T. Johnston. Motion prevailed.

President Bean requested that as many of the executive committee as could conveniently do so, remain over in Rochester to confer with him the following day, whereupon the meeting adjourned at 11 o'clock to meet at the call of the president.

Respectfully submitted,

C. E. Hoyt, *Secretary.*

W. R. Bean, *President.*

Minutes of Meeting of Executive Committee, American Foundrymen's Association, New York, Feb. 8, 1921.

A call for a meeting of the executive committee to be held in New York, Feb. 8, was sent out by President Bean. The date and place selected was with a view to conserving time and expense as a majority of the committee were to be in New York on that day to attend a meeting of the committee on awards.

The following were present: W. R. Bean, G. H. Clamer, C. E. Hoyt and V. E. Minich.

President Bean announced that a vacancy had occurred on the nominating committee due to the death of John Sherwin, and that nominations would be in order for the election of a member to fill the vacancy.

Mr. Hoyt nominated D. F. Ryan, of the Allyne-Ryan Co. of Cleveland; the nomination was seconded by Mr. Minich and Mr. Ryan duly declared elected a member of the nominating committee.

Mr. Hoyt called attention to the fact that the board had not elected alternate members of the nominating committee and that vacancies could be filled only by action of the board of directors, or by the executive committee empowered to act for the board in the intervals between meetings. Mr. Hoyt then moved the election of an alternate-at-large, and nominated Clifford B. Connelley, commissioner of labor of the commonwealth of Pennsylvania. Mr. Clamer seconded the nomination and Mr. Connelley was duly declared elected alternate-member-at-large of the 1921 nominating committee.

The secretary reported that at a meeting of the awards committee held earlier in the day, Bradley Stoughton, secretary of the American Institute of Mining Engineers, stated that he, together with W. M. Corse, had been delegated by the division of engineering of the National Research council, to present to the American Foundrymen's association the following resolution:

"WHEREAS, it is evident that need exists for a research on natural and synthetic molding sands as well as on the employment of greater proportions of used sands in molding operations;

RESOLVED: That, in co-operation with the American Foundrymen's association means be sought—

1. To collect all the information available in technical literature on these subjects in this and foreign countries;
2. By field operations of a practical, technical assistant, to study and formulate the practice in the best foundries of the country; and
3. To submit all the information so obtained to a committee composed of practical foundrymen and technical experts, with a request that this committee formulate suggestions for promising lines of research that might be followed to attain the desired ends.

The secretary stated further that the resolution offered had been discussed by members of the awards committee who respectfully recommended to the executive committee favorable consideration of the resolution.

Following discussion it was moved that the officers of the association be authorized to use the funds provided by the contribution of Messrs. Thomas W. and John C. Pangborn, provided it was found that the assistance offered by the National Research council was

deemed sufficient to make possible a comprehensive survey and report with the funds available. Motion prevailed.

There being no further business the meeting of the committee was declared adjourned.

C. E. HOYT, *Secretary.*

W. R. BEAN, *President.*

MINUTES OF MEETING OF THE COMMITTEE ON CONVENTION AND EXHIBITS HELD AT THE OLD COLONY CLUB, CLEVELAND, WEDNESDAY, MARCH 30, 1921.

The following members of the committee were present: President W. R. Bean, Messrs. H. R. Atwater, S. T. Johnston, V. E. Minich, T. W. Pangborn, J. P. Pero, and Secretary C. E. Hoyt. From C. S. Koch a telegram was received stating that it would be impossible for him to attend. Vice President C. R. Messinger, the other member of the committee, was absent in California.

The secretary reported on the cities from which invitations had been received and others which had been suggested by members of the committee. These included Atlantic City, Chicago, Cleveland, Columbus, Detroit, Indianapolis, Montreal, Rochester, St. Louis, Springfield, and Toronto.

The report developed the fact that in only three of the above named cities was it possible to secure both hotel and exhibit accommodations capable of providing satisfactorily for an attendance and exhibit of the extent of the 1919 and 1920 conventions and exhibitions.

In each of the three cities Atlantic City, Chicago, and Detroit, where both hotel and exhibit space could be obtained, conditions were not altogether desirable. At Atlantic City and Chicago the cost of exhibit buildings was prohibitive. At Detroit the total of exhibit space offered at the State Fair grounds was considered sufficient, but it was in different buildings and somewhat scattered.

In Rochester, a city which had been given favorable consideration because of its geographical location and splendid exhibit buildings, it was found that they could not offer in the fall of 1921 sufficient hotel accommodations to justify selecting that city. The invitation from the Detroit Foundrymen's associaion was supported by invitations from many other organizations in the city, and the use of the State Fair grounds and buildings was offered without cost to the association. In consideration of their most cordial and well-supported invitation a vote of thanks was given the Detroit Foundrymen's association.

Following the report of the secretary, President Bean raised the question of a convention without an exhibit. Considerable time was given to the discussion of such a plan, following which it was moved

by Mr. Johnston and seconded by Mr. Minich that the committee on convention and exhibits recommend to the board of directors that the annual convention be held, without exhibits, in New York, during October or November, 1921. Motion prevailed.

There being no further business the meeting adjourned.

Respectfully submitted,

C. E. Hoyt, *Secretary.*

Minutes of Meeting of the Executive Committee of the A. F. A., Held at 10:00 A. M., Saturday, May 28th, 1921, Old Colony Club, New York.

A meeting of the executive committee of the American Foundrymen's association was held at the Old Colony club, New York City, at ten o'clock Saturday morning, May 28, 1921.

The following members were present: President W. R. Bean, A. O. Backert, G. H. Clamer, V. E. Minich, and Secretary C. E. Hoyt. Absent: Vice President C. R. Messinger, and C. S. Koch.

Past President R A. Bull was present at the special invitation of President Bean, and also upon the request of absent members, Messrs. Koch and Messinger, who had had a conference with Mr. Bull two days before, and had asked that he be present to express their views on the main question to be considered, which was the resolution of the committee on convention and exhibits, adopted at a meeting of said committee in Cleveland, March 30. The resolution was as follows:

"*Resolved*: That the committee on convention and exhibits recommend to the board of directors that the annual convention be held, without exhibits, in New York, during October or November, 1921."

Prior to the meeting of the executive committee the report of the convention and exhibits committee had been submitted to each member of the board, nearly all of whom had expressed their views in writing. For this reason it was not thought necessary to call a meeting of the full board.

Messrs. Bean, Backert, Bull, Minich, and Hoyt were in New York the preceding day for the annual meeting of the Iron and Steel institute, and discussed informally the question of the next convention and exhibit. When the meeting was formally called by President Bean, letters from the members of the board were read, after which followed a general discussion resulting in a motion by Mr. Minich, seconded by Mr. Clamer, that the next convention and exhibit of the American Foundrymen's association be held in April or May, 1922, at a place to be selected by the convention and exhibits committee. This motion prevailed unanimously.

President Bean reported that on May 11 the following telegram was received from Herbert Hoover, secretary of commerce:

"I am anxious to inaugurate a complete monthly statistical report on the iron and steel industry, including stocks, production, and other data that will be of greatest value to the industry, and as a part of an efficient report on the business movement of the country. Will you co-operate by sending representative to a conference on the subject at this office Wednesday, May 18th, at two-thirty P. M.?"

As a result of this invitation it was decided that President Bean should attend the conference in Washington, and at the conclusion of his report of what took place at that time, the following resolution was adopted:

Resolved: That it is the sense of our executive committee that our association lend its moral support to Secretary Hoover in any ways possible, consistent with its purposes and in conformity with its by-laws, in his efforts to extend the field of usefulness of the department of commerce to industry and business; and specifically to offer our co-operation in the efforts now being made to establish a monthly statistical report on the iron and steel industry, including stocks, production, and other data, by sending a letter to all interested members urging their participation by supplying the requisite data monthly to the department of commerce; and further that we accompany the letter by a return card on which to signify their willingness or unwillingness to supply the data, we to tabulate the returns and communicate them to Secretary Hoover.

There being no further business the president announced that the meeting of the executive committee stood adjourned.

Respectfully submitted,

C. E. Hoyt, *Secretary*.

Approved

W. R. Bean, *President*.

Minutes of Meeting of Committee on Convention and Exhibits Held at the Cleveland Athletic Club, 9:30 A. M., Tuesday, Dec. 6, 1921.

All members of the committee were present, as follows: W. R. Bean, C. R. Messinger, C. E. Hoyt, H. R. Atwater, S. T. Johnston, C. S. Koch, V. E. Minich, T. W. Pangborn, and J. P. Pero.

The chairman, Mr. Bean, asked the manager of exhibits to read his report, copies of which had been sent to each member of the committee, together with blueprints showing layout of space in the Cleveland auditorium. This report contained recommendations as to charges for space, form of contract, rules and regulations, appropriation for advertising, and admission charge.

After a brief discussion it was moved by Mr. Pangborn and seconded

by Mr. Atwater, that the report and recommendations be accepted and the manager of exhibits authorized to proceed with arrangements accordingly. Motion prevailed.

The question of lease for Public Hall was then taken up. The manager explained that on Nov. 3 he received a letter from F. W. Thomas, director of parks and public property of the city of Cleveland, which was an agreement to give lease for a convention the week of April 24, and the necessary time for installation and removal, at a rental of $1240.00, and further, that a lease was being prepared by the legal department and would be executed within a few days.

The manager stated further that to date he had not received the lease, and had been given to understand that this was due to the result of the election of city officials on Nov. 6. He stated further, that Mr. Kennedy, manager of the convention bureau, had informed him that they were to have a conference this day with Mayor-Elect Kohler, for the purpose of asking him to honor a commitment of the present administration for the days and terms of occupancy of Public Hall for a convention and exhibit.

It was moved by Mr. Messinger and seconded by Mr. Minich, that under the circumstances the manager of exhibits should be instructed to proceed no further with exhibition plans, including publicity, until a lease was obtained, and in the meantime secure information as to conditions in other cities where a convention and exhibit might be held if developments did not make it seem advisable to go ahead with plans for a convention in Cleveland. The motion was unanimously carried.

There being no further business the meeting adjourned.

Respectfully submitted,

C. E. Hoyt, *Secretary.*

Minutes of Meeting of the Board of Directors of the American Foundrymen's Association, at the Cleveland Athletic Club, Cleveland, Ohio, Tuesday, December 6, 1921.

The annual meeting of the board of directors of the American Foundrymen's association was held in accordance with the provision of the by-laws.

The following members were present:

W. R. Bean, C. R. Messinger, C. E. Hoyt, H. R. Atwater, A. O. Backert, R. A. Bull, G. H. Clamer, Fred Erb, B. D. Fuller, Alfred E. Howell, W. A. Janssen, S. T. Johnston, C. S. Koch, V. E. Minich, and J. P. Pero.

Absent: S. B. Chadsey and L. W. Mueller.

Following roll call President Bean in the chair announced that owing to the fact that there had been no convention of the association held during the year, and no election of officers, the order of business would differ somewhat from that prescribed in the by-laws. The secretary then distributed copies of the order of business which had been specially prepared for this meeting.

Minutes of the meeting of Dec. 7, 1920 were read by the secretary and approved as read.

The secretary read his annual report which, on motion, was approved as read and ordered filed.

In giving the treasurer's report the secretary gave first a statement of the financial condition of the technical department, submitting an itemized statement of receipts and expenditures for the year, which showed a cash balance on Dec. 1, of $79.40, with no accounts payable, and accounts receivable totaling $2986.52.

Moved by Mr. Clamer that the report of the treasurer for the technical department be accepted and odered filed. Seconded by Mr. Howell, and carried.

The secretary then read his financial report for the department of exhibits, showing a cash balance on hand on Dec. 1, of $228.94, with account payable on a loan from technical department, of $1,000.00, and accounts receivable of $1008.98.

Moved by Mr. Bull that the report of the treasurer for the department of exhibits be accepted and ordered filed. Motion seconded by Mr. Howell, and carried.

The secretary then gave a financial statement of the research account, showing total contributions from all sources to be $4321.20, with expenditures to date on account of sand research work, $1680.35, leaving a balance of $2640.85.

Moved by Mr. Bull that the financial statement of the research account be accepted and filed. Seconded by Mr. Messinger, and carried.

The next in order was a report of the committee on convention and exhibits which was submitted by C. E. Hoyt, manager of the department of exhibits. The report reviewed the work of the committee during the past year, including detail of plans for 1922 exhibit which it had been announced would be held in Cleveland the week of April 24.

Moved by Mr. Pero that the report of the committee be accepted and filed. Motion seconded by Mr. Minich and carried.

Reporting for the executive committee the secretary read the minutes of a meeting of the committee held in New York on Feb. 8, and another meeting held in New York on May 28. It was moved by Mr. Bull that all of the actions of the executive committee for the past year be approved. Motion seconded by Mr. Howell, and carried.

The status of the board, due to no election being held during the year, was discussed, and it was decided that no action was necessary for the reason that the by-laws provide that the officers and directors shall hold office until their successors are elected and qualified.

The status of the officers elected by the board of directors was then considered, following which it was moved by Mr. Backert that all of the officers regularly elected by the board of directors at the annual meeting in Rochester, N. Y., Dec. 7, 1920, and the assistant secretary, Robert E. Kennedy, who had been elected by the executive committee, be continued in office until their successors are elected by the new board, and that their salaries remain as previously fixed by the board. Motion seconded by Mr. Howell, and carried.

Mr. Kennedy, chairman of the papers committee, submitted a report showing the number of papers that had been promised for the next convention, and submitted a tentative outline of the technical program for convention week. It was duly moved and seconded that the report be accepted. Motion carried.

The secretary read a letter from W. M. Corse, secretary of the Institute of Metals division of the A. I. M. E., stating that at an executive committee meeting on Nov. 9, he had been instructed to ask if the American Foundrymen's association would furnish preprints of the papers presented at the joint sessions, the number not to exceed 100 copies of each paper, to be sent to those who specifically request them.

Moved by Mr. Howell that this request be granted, with the understanding that the Institute of Metals division reciprocate and furnish a like number of their preprints for the joint sessions, for distribution to American Foundrymen's association members who specifically request them. Motion seconded by Mr. Koch, and carried.

Following a general discussion on the subject if issuing preprints to members, it was moved by Mr. Clamer that preprints should not be mailed out to members earlier than eight weeks prior to the convention date, except to those selected by the papers committee from whom written discussion was invited, and that to the members at large preprints be mailed out in three sets as nearly as possible eight weeks, six weeks, and four weeks prior to convention week. Motion seconded by Mr. Bull, and carried.

The secretary submitted a report for the committee on awards, reading from the minutes of the meeting of the awards committee held in New York on Feb. 8, at which time the committee considered the character of the medal to be adopted, and methods of awarding medals, following which the secretary was instructed to prepare a history of each endowment, and draft formal resolutions for the acknowledgment and acceptance of each, and also a form of deed or agreement setting forth the

conditions under which the endowment was accepted and would be administered.

The secretary reported the results of conferences and correspondence with artists and medal manufacturers, and exhibited designs which had been submitted, none of which were considered satisfactory. The secretary also submitted form of resolutions and articles of formal agreement which had been prepared and approved by the donors.

Mr. Howell moved that the report be received and the committee be continued with power to act. Motion seconded by Mr. Messinger, and carried.

Following discussion as to what awards should be given in 1922, Mr. Minich moved that this question be left in the hands of the awards committee with power to act. Seconded by Mr. Janssen, and carried.

Mr. Howell moved that the committee on awards be authorized to engage an artist who would work independently of the medal manufacturers, and assist the committee in securing a satisfactory design. Motion seconded by Mr. Bull, and carried.

An informal expression of opinion as to the character of the medal favored by the members of the board was asked for for the guidance of the committee on awards.

The meeting adjourned for lunch at 1 p. m., and resumed at 2:30 p. m.

Mr. Howell, chairman of the promotion and membership committee gave a verbal report which was supplemented by data read by the secretary.

Mr. Howell, chairman of the committee appointed by the president to prepare resolutions on the death of Past President W. A. Jones, offered the following resolutions which had been drafted, and moved their adoption:

"On May 30, 1921, Mr. W. A. Jones died at his home in La Porte, Ind. He suffered an apoplectic stroke about a year before his death and never fully recovered. In early life he was in business at Marseilles, Ill., and later was connected with the Link-Belt Co. of Chicago.

In 1890 Mr. Jones founded the W. A. Jones Foundry and Machine Co., of which he was president up to the time of his retirement.

Mr. Jones was fond of travel and hunting and a very ardent outdoor man, in addition to his business activities. He joined the American Foundrymen's association in 1897—one year after its founding and attended regularly for 20 years. The meeting of 1917 in Boston was the last he was able to attend.

His great interest, his ability and prominence in the industry led to his election as president at the first Chicago meeting in 1900, and he presided at the Buffalo convention in 1901. He was an honorary life member of this association and as such, a member of the advisory board. In view of our bereavement your committee reports that

WHEREAS, in His inscrutable wisdom, our Maker has taken from us our friend and honored ex-president, Mr. W. A. Jones, and

WHEREAS, his passing has deprived us of one to whom we looked for counsel and experienced advice,

BE IT RESOLVED—by the board of directors of the American Foundrymen's association, that we deeply regret his loss, and that this expression of our regard and respect for him be recorded on the minutes and a copy of the same be transmitted to his family with our sincere sympathy."

Respectfully submitted,

R. A. BULL,
S. T. JOHNSTON,
ALFRED E. HOWELL, *Chairman.*

Mr. Howell's motion was duly seconded and carried.

Mr. Backert, of the committee appointed by the president to prepare resolutions on the death of past president J. S. Seaman, offered the following resolutions:

"The board of directors of the American Foundrymen's association, on behalf of the membership, desires to express its deep appreciation of the uninterrupted interest and activity of Joseph Sidney Seaman in the affairs of this organization, of which he was a founder and a past president. His helpful counsel and deep interest prevailed for a quarter-century, from the time the association was formed until his death, June 15, 1921. The affection and esteem in which he was held were cumulative with the years of his affiliation with this society. The personal and filial regard of his associates was fittingly expressed by the title of "Daddy," conferred upon him as a token of affection, and appreciation of his paternal interest in this body. Therefore,

BE IT RESOLVED THAT, The American Foundrymen's association through its board of directors in annual meeting assembled, in this manner tender this, another tribute to the memory of a man whom we loved, and whose influence on behalf of this organization will not terminate with his passing, but will always endure, and

BE IT FURTHER RESOLVED THAT, We extend to the members of his family our deep sympathy for their great sorrow which we share."

Respectfully submitted,

A. O. BACKERT,
R. A. BULL, *Chairman.*

It was moved by Mr. Bull that the resolutions be adopted by a rising vote, which was given.

The secretary reported on the relations established between the Institution of British Foundrymen and the American Foundrymen's association, resulting in the inauguration of a plan for an exchange of papers and the presentation of a paper by George K. Elliott of the American Foundrymen's asociation, at the annual meeting of the Institute of British Foundrymen at Blackpool, England, Sept. 14, 1921.

It was reported that official invitations had been received from the

Institute of British Foundrymen by the president, vice president, and secretary of the American Foundrymen's association to be the guests of the Institute of British Foundrymen at their annual meeting to be held in Birmingham, June 14, 1922.

Mr. Clamer moved that a vote of thanks be extended to the Institute of British Foundrymen, and that the board of directors authorize the secretary to extend a similar invitation to the officers of the Institute of British Foundrymen to be our guests at our 1922 convention.

Mr. Fuller, chairman of the committee on safety and sanitation, who had been authorized at the meeting of the board on Dec. 7, 1920, to represent the association in the matter of the adoption of a foundry safety code by the American Engineering Standards committee, made a verbal report and read copies of correspondence to show what obstacles had been met, and what progress had been accomplished.

Mr. Hoyt moved that the report be accepted and Mr. Fuller authorized to continue the negotiations on the part of the American Foundrymen's association. Motion seconded by Mr. Johnston and carried.

Mr. Bull, chairman of the Committee on Revision of by-laws, submitted the following as revisions to Articles IX and X, "nomination and election of officers and directors, and Article XII, Section 1, "date of the annual meeting of the board of directors.

ARTICLE IX.

Nomination of Officers and Directors

Section 1. There shall be created annually a nominating committee consisting of the last three living past presidents of the association, and four other members, to be elected by the members of the association at least four months prior to the first day of the annual convention. The manner of their election shall be prescribed by the board of directors.

Section 2. The nominating committee shall prepare a list of candidates for officers and other directors, which list shall be mailed to all members of the association at least ninety days prior to the first day of the annual convention.

Section 3. Any twenty-five members, by petition filed with the secretary not less than sixty days prior to the first day of the annual convention, may nominate candidates for officers and directors.

ARTICLE X

Elections

Section 1. Should no other candidates for officers and directors be nominated in the manner provided in Article IX, Section 3, then the candidates nominated by the nominating committee shall be declared elected for the terms of office for which they were nominated.

Section 2. In the event of there being candidates nominated for officers and directors other than those named by the nominating committee in the manner provided for in sections 2 and 3, article IX, then the election of officers and directors shall be by ballot of the members. The ballots shall not be counted unless they reach the office of the secretary at least thirty days prior to the annual convention of that year.

Section 3. In the case of election by mail ballot it shall be the duty

of the secretary to have printed and mailed to all members in good standing, ballots bearing the names of all candidates nominated in accordance with the provisions of sections 2 and 3 of Article IX, and to prepare a correct list of members qualified to vote and to hold office, which list the secretary shall give each judge of election when he is appointed.

Section 4. In the case of election by mail ballot, the president shall appoint, at least thirty days before the first day of the annual convention, three judges of election who shall have sole charge of the canvassing of votes. When the polls are closed the judges shall examine all ballots cast, and shall certify the result of the election to the president before the first day of the annual convention of the association. The newly elected officers and directors shall assume office at the annual meeting of the board of directors following their election, as provided for in the order of business in Article XII.

ARTICLE XII

Board Meetings

Section 1. The annual meeting of the board of directors shall be held within ninety days of the date of adjournment of the annual convention, at a time and place designated by the president.

Mr. Atwater moved that the report of the committee be approved, and that the revisions to the by-laws be submitted to the members for approval by mail ballot in the manner prescribed in article XVII of the by-laws, the revisions, if approved, to take effect immediately following the adjournment of the next annual meeting of the association.

Assistant Secretary Kennedy submitted a report as secretary of the general committee on sand research, showing what had been accomplished to date, which report was supplemented by Mr. Bean, and Mr. Bull chairman of the general committee.

The secretary submitted a report of progress on pattern standardization, which was supplemented by a report from Mr. Erb, a member of the sub-committee appointed by M. Reid, general chairman.

It was suggested that the secretary mail to each member of the board, copy of a letter on Standard Pattern practice, written by Mr. Melvin, secretary of the National Association of Pattern Manufacturers.

Mr. Hoyt moved that 50 per cent of the traveling expenses of the members of the board and the executive committee be paid by the technical department, and 50 per cent by the department of exhibits, for attendance at all meetings except meetings held during convention week, and further that all traveling expenses of members of the papers committee and other standing committees of the technical department be paid entirely out of the funds of the technical department, and that the traveling expenses of members of the convention and exhibits committee be paid entirely out of the funds of the exhibit department. Motion seconded and carried.

Moved by Mr. Hoyt that the customary per diem of $15.00 be paid out of the funds of the department of exhibits, to all members in attendance at regularly called meetings of the board of directors, executive

committee, and convention and exhibits committee, except meetings held during annual convention week. Motion seconded by Mr. Pero, and carried.

Following discussion on the adoption of standards and specifications, Mr. Backert moved that this question be taken up with the American Society for Testing Materials with a view to securing American Foundrymen's association representation on all American Society for Testing Materials committees dealing with specifications and methods in which the American Foundrymen's association is interested.

The secretary read a letter from Mr. J. L. Linsley, chairman of the iron section of the National Association of Purchasing Agents, submitting draft of pig iron contract, and requesting consideration, and if consistent, approval by the American Foundrymen's association.

Following general discussion Mr. Backert moved that the National Association of Purchasing Agents be notified that after due consideration the board of directors concluded that it was not within the province of the American Foundrymen's association, because of its technical nature, to unqualifiedly adopt this contract form, but that the American Foundrymen's association is in sympathy with the adoption of a standard pig iron contract. Motion seconded by Mr. Fuller and carried.

President Bean raised the question of the adoption of pig iron specifications other than for foundry iron. It was suggested that this question be referred to the joint American Society for Testing Materials and American Foundrymen's association committee for its consideration.

The secretary read a letter from W. M. Stewart, director of bureau of the census of the Department of Commerce, asking that the board adopt a resolution urging its members to co-operate with the bureau of the census in the making of the biennial census of manufacturers covering operations for the calendar year 1921, which is in conformity with the act of congress approved March 3, 1919. •This census will be taken shortly after the beginning of the year, 1922.

The following resolution was offered:

"*RESOLVED*: That the American Foundrymen's association recognizes the importance of the census of manufacturing industries in the United States, which is required to be taken by the act of congress approved March 3, 1919, and it recommends to members that they co-operate earnestly with the director of the bureau of the census and furnish the information required to make the statistics full and accurate."

Mr. Erb moved the adoption of the resolution, and that it be printed in the association bulletin. Motion seconded by Mr. Fuller and carried.

The secretary called attention to the contribution of $1000 to the research fund, made and announced on February 23, 1921, by Mr. Herbert S. Simpson of the National Engineering Co., and it was moved by Mr. Minich that a vote of thanks be extended to Mr. Simpson for his

most generous contribution. Motion seconded by Mr. Koch and carried.

The meeting adjourned at 6:10 p. m.

Respectfully submitted,

C. E. Hoyt, *Secretary.*

Minutes of Meeting of Board of Directors of the American Foundrymen's Association, Held at the Hill Country Club, Rochester, N. Y., Tuesday Evening, June 6, 1922.

This meeting followed the alumni dinner of the officers, directors, and past officers of the association.

Directors present: C. R. Messinger, H. R. Atwater, A. O. Backert, R. A. Bull, G. H. Clamer, Fred Erb, B. D. Fuller, S. T. Johnston, C. S. Koch, V. E. Minich, and C. E. Hoyt. There were also present C. B. Connelley, L. W. Olson, and A. B. Root Jr., directors-elect, past president L. L. Anthes, and past secretaries John A. Penton and Richard Moldenke, and as a special guest Frederick J. Cook of Birmingham, England, who was in attendance at the convention as the representative of the Institution of British Foundrymen.

In the absence of President Bean, due to serious illness, vice President Messinger called the meeting to order, and read the following telegram from President Bean:

"While bodily ill makes impossible my physical presence I shall be with you in spirit in the opening session this afternoon and in all the activities of the week. The period since our last convention has been one of many vicissitudes for most of those in the foundry industry but I am looking forward with much hope to the year ahead."

Following the reading of the telegram the Chair appointed Mr. Clamer and Mr. Minich as a committee to send a "flowergram" and night letter of greetings to President Bean.

Attention was called by the Chair to the death, during the year, of Henry A. Carpenter, a charter member and past officer and director of the association. A number of those present most intimately associated with Mr. Carpenter in association work spoke of his great interest in the association from the time it was organized until his death. It was moved by Mr. Bull that a committee be appointed to draft resolutions on the death of Mr. Carpenter. The Chair appointed B. D. Fuller, A. O. Backert and Alfred E. Howell.

Mr. Bull moved that the board of directors recommend to the association in convention the election of President W. R. Bean to honorary membership in the association. Motion duly seconded and carried unanimously.

The Chair called for a report of the committee consisting of W. R. Bean, R. A. Bull, and A. H. Jameson, appointed to confer with a committee from the American Society for Testing Materials on the question of closer co-operation between the two associations in the consideration of specifications and methods in which the American Foundrymen's association is interested. Mr. Bull as chairman of the American Foundrymen's association committee reported that the following recommendations were unanimously agreed upon by the joint committee:

(a) That the American Foundrymen's association be elected to membership on those American Society for Testing Materials committees dealing with specifications and methods in which the American Foundrymen's association is interested.

(b) That the chairman of the American Foundrymen's association committees be designated as the American Foundrymen's association representatives on the subcommittees of the appropriate American Society for Testing Materials committees.

(c) Recommend to the American Foundrymen's association that its committees function by reviewing American Society for Testing Materials specifications as they stand, either recommending endorsement by the American Foundrymen's association, or submitting criticisms for transmittal to the American Society for Testing Materials committees. It is suggested that with respect to existing American Society for Testing Materials tentative specifications, endorsement be deferred until their adoption as standard, and that in the meantime any criticism of such specifications be transmitted to the American Society for Testing Materials committee.

(d) That with reference to publication by the American Foundrymen's association of American Society for Testing Materials specifications, publication take the form of an endorsement of such specifications, which will be printed as American Society for Testting Materials specifications.

On motion duly seconded the report of the committee was unanimously accepted, with the recommendation that the president be instructed to appoint the necessary committees, and that the chairman of each committee be designated by the president as the American Foundrymen's association representative on the American Society for Testing Materials committee, provided that the recommendations of the joint committee were also approved by the executive board of the American Society for Testing Materials.

The Chair called attention to the following resolution which was presented at the International session on June 6, and recommended to the board of directors for action:

RESOLVED: That the American Foundrymen's association will welcome the resumption of deliberations looking toward interna-

tional agreement upon methods of foundry procedure and specification. That the American Foundrymen's association deems an early agreement on an international test bar, and the purchase and use of pig iron by its analysis only, essential in the interest of intensificd export trade. The American Foundrymen's association is prepared to co-operate with foundrymen's and engineering societies of other countries to this end.

A general discussion in international standards and specifications followed, in which Mr. Cook of the Institution of British Foundrymen took an interested part. Following the discussion it was moved by Mr. Bull that the president be authorized to appoint a committee of three directors to consider the adoption of an international test bar, with full power to go as far as they deemed advisable in consideration of the subject as a whole, and make recommendations to the board.

The Chair read a communication from the American Engineering Standards committee, asking the association to appoint a representative on the committee on Standard Methods of Laboratory Sampling and Analysis of Coke. The motion was duly seconded and the president was authorized to appoint a representative on this committee.

Mr. Fuller, chairman of the American Foundrymen's association committee on Safety Code reported progress in the adoption by the American Engineering Standards Committee, of the foundry safety code sponsored jointly by the American Foundrymen's association and the National Founders' association. A vote of thanks was extended to Mr. Fuller for the splendid work he has done as chairman of this committee.

Following general conversation on association activities in which nearly all those present took part, the meeting adjourned.

Respectively submitted,

C. R. Messinger, *Vice President.* C. E. Hoyt, *Secretary.*

Minutes of the Meeting of the Board of Directors of the American Foundrymen's Association Held at the Offices of the Association, Chicago, August 29, 1922.

In pursuance of the provisions of the by-laws a call was made for the annual meeting of the board of direcors at the office of the association, Marquette building, Chicago, at 10 a. m., Tuesday, Aug. 29.

By common consent of all the members of the board of directors it was understood that this meeting would be adjourned to a later date.

At the appointed hour the secretary reported no quorum present and the meeting was adjourned to meet at 10 a. m. Tuesday, Oct. 3, at the Drake hotel, Chicago.

Respectively submitted,

C. E. HOYT, *Secretary.*

MINUTES OF THE ADJOURNED ANNUAL MEETING OF THE BOARD OF DIRECTORS OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION, HELD AT THE DRAKE HOTEL, CHICAGO, 10 A. M., TUESDAY, OCT. 3, 1922.

Meeting called to order by Vice President C. R. Messinger in the chair.

Before taking up the regular order of business, Mr. Messinger made brief mention of the death of past President and Director J. P. Pero, at his home in Indian Orchard, Mass., on Sept. 23, 1922, and appointed A. O. Backert, and B. D. Fuller as a committee to prepare resolutions to be spread upon the records and sent to the members of Mr. Pero's family.

The roll call showed the following directors present: C. R. Messinger, H. R. Atwater, A. O. Backert, R. A. Bull, G. H. Clamer, Fred Erb, B. D. Fuller, S. T. Johnston, V. E. Minich, L. W. Mueller, and C. E. Hoyt. There were also present Assistant Secretary Robert E. Kennedy, and directors-elect C. B. Connelly, L. W. Olson, and A. B. Root Jr.

Absent: W. B. Bean, S. B. Chadsey, C. S. Koch, Alfred E. Howell, and W. A. Janssen.

The Chair announced a quorum present.

The secretary read letters and telegrams from President Bean expressing sincere regret that he was not able to be present. Messages were also received from others not present, expressing regret that conditions made it impossible for them to attend.

The Chair announced that he would appoint G. H. Clamer, L. W. Olson, and R. A. Bull, members of the finance committee.

The secretary read his annual report to the board of directors, whereupon it was moved that the report be accepted and filed.

The report of the treasurer was read. In submitting the report of the treasurer for the technical department, Mr. Hoyt stated that the fiscal year ended Dec. 31, at which time the books would be audited. He presented a statement of receipts and expenditures from Jan. 1 to Oct. 1, showing a cash balance of $1323.90, with accounts receivable of $1806.00 on account of dues, and $2000.00 as the balance of the appropriation of $3000.00 authorized at the meeting

of the board, Dec. 6, 1920, following the Columbus convention, to be paid out of the receipts of the exhibit of that year. On motion the report was received and referred to the finance committee.

Mr. Hoyt as manager of exhibits submitted a report of the exhibit held in conjunction with the Rochester convention, which was supplemented by the auditor's report as of date of Aug. 31. This report showed a total cash balance, including the petty cash fund of $7,436.17, with accounts receivable of $1,693.03. Supplementing the auditor's report the manager exhibited a detailed itemized statement of receipts and expenditures. On motion the report was received and referred to the finance committee.

Reporting for the executive committee the secretary stated that no meetings of the executive committee had been held since the last annual meeting.

Mr. B. D. Fuller, chairman of the committee to submit resolutions on the death of Henry A. Carpenter, submitted the following:

To the Board of Directors of the American Foundrymen's Association:

Your committee appointed to memorialize our loss in the passing of Henry Alden Carpenter begs to report:

"We cannot make swift coming death a little thing, nor bring again the pleasures of past years. Nor can we, by aught we can say, but slightly alleviate the sorrows we feel, or the grief of those most intimately associated by ties of kinship and contact in his daily relations.

"We who knew him in our councils, learned to admire him for his manly traits, his courage, and to honor him for his wholesome outlook on life. We valued his sound advice and loved him for his kindliness and friendship. We cannot add to the luster of his name by futile words that but remind us of what each already knows, but, by voicing our estimate of him we may strengthen our own spirit to emulate his example in winning the hearts of his comrades. We fain would lighten the distress of his dear ones by our expression of sympathy and by recording our appreciation of Henry A. Carpenter.

"The story of his life and achievements has been elsewhere told. His career was all too short for one so useful and effective in all he undertook and so influential by reason of his strong and winning personality.

"We knew him from the beginning of this association, of which he was a charter member, and it is this relation which justifies the special tribute of this board. For many years on the official board, he would have been its president had not his modesty and pressing duties occasioned his favoring others. We felt that he was the friend of each, and that there was nothing in reason that he would not cheerfully, manfully and effectively do for the advancement of our association's interest, and interest to the industry in whose behalf we labored, and in which he accomplished so much. He was unselfish, and his wholeheartedness was an inspiration.

"On Jan. 20, 1922, at his home in Providence, aged 55 years, Henry A. Carpenter left us to join that innumerable throng, which we too must join to solve the great mystery. May we meet him

again and grasp him by the hand and hear again his fearless "Cheero!" By such hopes, for him and others of the noblest and the best, are we sustained and soothed.

"We ask that this appreciation be recorded on the minutes of the association, and a copy conveyed to his family with our sympathy and unfaltering trust in ultimate good to all."

Respectfully submitted

Benjamin D. Fuller
A. O. Backert
Alfred E. Howell

Committee

On motion, duly seconded the resolutions were accepted by a rising vote.

Mr. Kennedy for the committee on standard pattern practice submitted a report. It was moved to accept the report and to refer the appointment of a new committee to the incoming board. Motion prevailed.

Mr. Bull, chairman of the joint committee on molding sand research of the American Foundrymen's association and the National Research council, gave an interesting report of progress made by that committee, and stated that the budget which had been prepared by the executive committee, covering estimated expenses for the coming year, amounted to $15,000.00, and that at a recent meeting of the executive committee of the joint committee for molding sand research he had been authorized to appoint a committee to raise the funds. On motion the report was received.

Mr. Messinger suggested that a report be prepared outlining what has been accomplished in the sand research work and what it is proposed to do, and that it be printed or typed in convenient form to be submitted to all who are or should be interested in this important work. Mr. Bull stated that such a report would be prepared.

Suggestions were made as to various sources from which funds might be received, and Mr. Clamer suggested the possibility of securing a special appropriation from congress for this work, stating that similar appropriations had been made up to $15,000.00.

Mr. Root moved that Major Bull as chairman of the joint committee on molding sand research, with the approval of the president, appoint a finance committee to raise and handle the funds required in this work. Motion prevailed.

Mr. Bull brought up the question of expenses incurred by certain members of the research committee, and recommended that action be taken by the board, authorizing that they be reimbursed. On motion this question was referred to the finance committee.

Mr. Hoyt moved that the board authorize that the National En-

gineering Simpson Fund, now amounting to $1040.52 be made available for conducting sand research work. Motion prevailed.

Mr. Fuller, chairman of the committee on safety, sanitation and fire prevention, reported that the foundry safety code which had been sponsored by the American Foundrymen's association and the National Foundrymen's association had been approved by the American Engineering Standards committee and was now in the hands of the printers. It was moved that Mr. Fuller's report be received and a vote of thanks given him for the work he has done. Motion prevailed.

Reporting for the committee on awards, the secretary read the minutes of the meeting of the committee held in New York, April 18, 1922, recommending to the board of directors plans for creating an awards board and for the giving of awards in 1923. On motion the report was received and referred to the incoming board.

Mr. Fuller, chairman of the committee appointed to judge the devices submitted and displayed at the Rochester convention in competition for the Obermayer award, reported that after carefully considering all of the drawings and models of devices submitted, the committee were unanimous in recommending to the board that the award be given to Edwin Jory, of the National Transit Pump & Machine Co., Oil City, Pa.

It was moved that the report be accepted and that the board ratify the recommendation of the committee that an award be made to Edwin Jory, and that a suitable certificate and appropriate prize at a total cost of not to exceed one year's income from this fund, be procured by the secretary and presented to Mr. Jory. Motion seconded by Mr. Johnston and carried.

The secretary reported that the plan of co-operation with the American Society for Testing Materials, which had been submitted to and approved by the board at the meeting in Rochester on June 6, 1922, had later been approved by the executive committee of the American Society for Testing Materials and the American Foundrymen's association representatives had already been appointed on nine American Society for Testing Materials' committees.

The secretary read a copy of the report submitted at the Rochester convention by the committee on steel foundry standards, recommending the cancellation of standards adopted by the American Foundrymen's association to the end that the association might cooperate with the American Engineering Standards committee in the adoption of standards. The secretary stated further, that this report was received and referred to the board of directors for their consideration.

Several directors spoke in favor of American Foundrymen's as-

sociation co-operation with the American Engineering Standards committee, and it was moved by Mr. Bull that the question of co-operation and changing of standards previously adopted be referred to the executive committee with full power to act. Motion prevailed.

The chair brought up the question of an international test bar, which was discussed at the meeting of the board in Rochester on June 6, as the result of a resolution which had been presented by Walter Wood at the international session, which resolution was referred to the board of directors. Mr. Messinger stated further that the board, after considering the resolution, had instructed the president to appoint a committee of three directors to investigate and make recommendations to the board; that President Bean had appointed R. A. Bull, C. R. Messinger and C. E. Hoyt on this committee and that the committee had a report to make, the discussion of which would undoubtedly take a great deal of time as this was a very important subject.

After brief discussion it was moved that the report of the special committee be passed to the new board, which would convene immediately after the adjournment of this board. Motion prevailed.

Mr. Clamer, chairman of the finance committee, announced that the reports of the treasurer, and the manager of exhibits, and the auditor's report for the department of exhibits had been examined and approved, and that the committee would make the following recommendations:

First: That the balance of $2000 previously appropriated, be transferred from the funds of the exhibits department to the technical department.

Second: That $1000 be transferred to the funds of the technical department and $250 given to the Institute of Metals Division of the American Institute of Mining Engineers, out of the receipts of the Rochester exhibit.

On motion the report was received and the disposition of funds as recommended, authorized.

Mr. Hoyt stated that since the books of the department of exhibits were audited, accounts receivable of $1693.03 had been reduced to $892.21, and that deducting the appropriations which had just been authorized from the cash on hand Oct. 1 would leave a cash balance in the exhibit department of $3865.29.

The secretary read the following report of the judges of election for officers and directors, presented at the closing session of the association at Rochester, June 9, 1922:

"The judges of election have to report that they have canvassed

the ballots for officers and directors, and find that a total of 499 ballots were cast for the following:

For president, C. R. Messinger
For vice president, G. H. Clamer,
For directors for three years:
C. B. Connelley,
Fred Erb,
C. E. Hoyt,
L. W. Olson,
A. B. Root Jr.

Signed: R. F. HARRINGTON,
W. J. BRANDT, *Judges.*

It was moved that the report of the judges be received and the election of officers and directors as shown in the report be confirmed. Motion prevailed.

A. O. Backert, chairman of the committee appointed by the president to prepare resolution on the death of Past President J. P. Pero, presented the following and moved their adoption:

The ranks of the pioneers in organization work among American foundrymen was further decimated on Sept. 23, 1922, when John P. Pero joined the silent legion. To him was accorded only a few years of relaxation after he terminated an active and colorful career of half a century in the casting industry. It was at Indian Orchard, Mass., that *finis* was written and life's scroll recorded his age at 66 years.

Always deeply interested in promoting educational work among foundrymen, in 1887 he conceived the idea of forming an organization of casting manufacturers to promote an exchange of views on technical and practical subjects involved in casting production. The small group which he gathered around him formed the New England Foundry Foremen's Association, which is claimed to be the original American association devoted to educational work among foundrymen. He served as secretary of this society for many years. He was active in the organization of the American Foundrymen's Association in 1896 and until the time of his death he unselfishly devoted himself to its interests. In recognition of his services he was honored with the presidency of this organization in 1917. Honorary membership also was conferred on him and his passing left a vacancy on the board of directors.

Although trained in gray iron foundry practice, he mastered the intricacies of malleable casting production and ranked with the leading experts of the world in this branch of foundry work.

Of a magnetic personality that attracted closely to him all with whom he came into contact, John P. Pero numbered his friends by his acquaintances. His optimism and cheery disposition radiated a kindness of character that left only affection in its wake. Contact with him in the councils of the American Foundrymen's Association was as inspirational as his advice was sound. Therefore

BE IT RESOLVED that, The American Foundrymen's Association, through its board of directors, hereby expresses its great appreciation

of the uninterrupted interest and activity of John P. Pero in its behalf and records in this way its great sorrow over his loss.

BE IT FURTHER RESOLVED that this expression of regard and appreciation be included in the minutes and that a copy be transmitted to his family to whom we extend our deep sympathy and with whom we share their great loss.

Respectfully submitted,
A. O. BACKERT,
BENJ. D. FULLER, *Committee.*

The foregoing resolutions were adopted by a rising vote.

The secretary reported that at the annual business meeting of the association at Rochester, Friday, June 9, 1922, the members present, acting upon the recommendation of the board of directors, duly elected Mr. Wyndham Randolph Bean to honorary membership in the American Foundrymen's association. Mr. Minich moved that the election of Mr. Bean to honorary membership be confirmed, and the motion being duly seconded was unanimously carried.

The chair announced that following luncheon we would be escorted by Mr. Bowman, secretary of the convention bureau of the Chicago association of commerce, to the municipal pier on a trip of inspection and that if there was no further business, a motion would be in order for final adjournment of the retiring board of directors of the American Foundrymen's association.

On motion the meeting adjourned at 12:30 p. m.

Respectfully submitted,
C. E. HOYT, *Secretary.*

C. R. MESSENGER, *Vice President.*

Report of the Manager of Exhibits

For the Period Ending October 3, 1922

To the Board of Directors, American Foundrymen's Association, Inc.:

We are pleased to submit the following as a report for the Department of Exhibits covering the exhibit held at Exposition Park, Rochester, N. Y., June 5 to 9, 1922.

The books of the department were audited on Aug. 31. The last previous audit of the books was on Dec. 31, 1921. Therefore, the statement of receipts and expenses shown in the report are only for a period of eight months. To make the financial report covering the Rochester exhibit comparable with reports covering previous exhibits, it would be necessary to include the expenses of the last four months of 1921, which would just about date back to the time when preparations were started for the 1922 exhibit.

As you know, it was originally planned to hold an exhibit in Cleveland the week of April 25. Floor plans were made and prospectus material prepared and approved by the Exhibits Committee in November. It then developed that there was a possibility of the Public Auditorium in Cleveland not being completed in time for our occupancy. The issuing of our prospectus was held up and on Jan. 17 of this year His Honor, the mayor of Cleveland, advised a committee consisting of Messrs. A. O. Backert, E. S. Carman and C. E. Hoyt, who called upon him, that it would be impossible for him to give us a lease on the Auditorium for the spring or early summer because of the uncertainty as to date of completion.

Negotiations were immediately opened with Rochester with the result that on Jan. 26 notice was sent out that the convention and exhibit of the association would be held in Rochester the week of June 5. While the change in cities had delayed us and the time was limited for making preparations, a successful exhibit was held. There were in all 178 exhibitors using a total of 46,787 square feet of exhibit space, exclusive of aisles, an average of 260 square feet per exhibitor.

The total of space used was considerable less than that used in Columbus in 1920 or in Philadelphia in 1919 but exceeded the total of space used at any previous exhibit held under the auspices of our association.

The buildings at Exposition Park were well adapted to our purpose, permitting of the operating of all classes of equipment. The total number of exhibitors using electrical power was 86 and compressed air 26. The total number of motors connected was 123; the total rated horsepower 476.

The largest single item of expense in connection with putting on the exhibit was for electrical work, due to what semed to us very arbitrary regulations by the authorities requiring that all wiring be run in conduit, the regulations being more rigid than in any city where we had exhibited in the past. We were also obliged to pay the usual penalty of opening on a Monday and of the total of 2400 hours of electrical work, over 1700 was done on double time Saturday afternoon and Sunday.

In the years 1913, 1914 and 1915 under F. & M. E. Co. management, the exhibits opened on Saturday previous to convention week, thereby avoiding the expense and inconvenience of opening on a day preceded by a day and a half of closed freight offices and yards and double time for all mechanics employed.

We have discussed this question with a number of exhibitors and with the managers of other exhibits and all are agreed that if possible this condition should be avoided, and we would recommend for your consideration a Saturday opening for the next exhibit.

The auditor's report shows total receipts for space as $30,207.50, an average of $.645 per square foot. The average price per square foot at Columbus at the previous exhibit was $.649, only $.004 difference. The report also shows a cash balance on Aug. 21 of $7,436.17 and accounts receivable of $1,693.03. Since the audit accounts receivable have been reduced to $892.21 and the cash balance on Oct. 1 was $7,115.29.

There is, however, on record an order from the Board of Directors that $2,000.00 be transferred to the technical department from the 1920 exhibit at Columbus but which transfer has not yet been made and which we would recommend being made at this time. If in addition the usual appropriation of $1,000.00 to the technical department and $250.00 to the Institute of Metals Division of the A. I. M. E. be voted today, it would reduce our cash balance to $3,865.29. In our sinking fund we have U. S. Liberty Bonds amounting to $11,500.00.

The auditor's report shows total receipts and disbursements under each ledger account. To supplement this we have prepared for you a detailed statement of disbursements under each ledger head. We also have prepared a statement showing the names of all exhibitors and the amounts paid by each for exhibitor's permits, space and power.

In closing we wish to express our great appreciation of the helpful co-operation of the officers and directors during the past year.

Respectfully submitted,

C. E. Hoyt, *Manager of Exhibits.*

Auditor's Report for Department of Exhibits

Mr. W. R. Bean, President,
American Foundrymen's Association, Inc.,
Chicago,

Dear Sir:—

I have audited the books of the exhibit department of the American Foundrymen's Association, Inc., for the period from Jan. 1 to Aug. 31, 1922, and append hereto the following statements:

Receipts and Expenses for the period
Trial Balance as at Aug. 31, 1922

The period under audit comprises the operating of the association's convention and exhibit held at Rochester, N. Y., in June, 1922. It should be noted that the result for the period takes into consideration the expenses of administration for the eight months only.

The actual work on the exhibit started in October, 1921, and there is thus a period of three months in 1921 in which administrative expenses were incurred for the 1922 convention and exhibit. Examination reveals that these expenses totaled $2,518.87 and the excess of receipts over expenses for the eight months' period in 1922 as shown on the appended statement and which amounts to $10,178.50, should be reduced by $2,518.87 in order to arrive at a figure which will reflect the real result of the department's operations. The net result of the Rochester exhibit may, therefore, be stated as a credit of $7,659.63.

The net receipts during the eight months of 1922 were applied as follows:

Cash in Bank—increased by	$6,994.45
Accounts Receivable—increased by	684.05
Loan from Bank—repaid	2,500.00
Loan from Technical Dept.—repaid	500.00
	$10,678.50
less	
Refund by City of Cleveland of rent paid in advance	500.00
	$10,178.50

I have been assured that all the expenses of the convention have been recorded on the books.

The Liberty bonds of the second issue converted aggregating

$11,500.00 were shown to me. The market value of these at the present date is $11,509.20 against a purchase cost of $10,099.85.

Yours truly,

R. T. Pritchard,
Chartered Accountant.

AMERICAN FOUNDRYMEN'S ASSOCIATION, INC.
DEPARTMENT OF EXHIBITS
Statement of Receipts and Expenses from Jan. 1 to Aug. 31, 1922

RECEIPTS

At Rochester Convention		
Space Rental	$30,207.50	
Gate Receipts	1,709.54	
Exhibitors' Permits	4,450.00	$36,367.04
Interest on Bonds		244.38
Interest on Bank Balances		71.79
		$36,683.21

EXPENSES

Advertising	$ 3,709.41	
Badges	382.00	
Booths	3,949.83	
Cleaning and Repairing	146.05	
Committee Traveling Expenses	357.27	
Convention Expense	778.39	
Entertainment	2,000.00	
Exchange	18.55	
General Expense	79.34	
Installation—Labor	485.97	
Installation—Superintendents, etc.	904.00	
Insurance	229.25	
Manager's Salary—8 months	5,066.68	
Manager's and Assistant's Travelling Expense	846.71	
Office Expense	99.99	
Postage	332.56	
Power less receipts	2,435.77	
Printing and Stationery	1,160.37	
Registration	771.83	
Office Rent	344.00	
Stenographers	1,687.20	
Telephone and Telegraph	218.56	
Watchman and Doormen	501.00	26,504.71
Excess of receipts over expenses		$10,178.50

Trial Balance, Aug. 31, 1922

Accounts Receivable	$1,693.03
Cash in Bank	7,236.17
Petty Cash Fund	200.00
Furniture and Equipment	523.50
U. S. Liberty Bonds, $11,500 Second Issue Converted	10,099.85
Surplus Aug. 31, 1922	$19,752.55

Annual Report of the Secretary-Treasurer

To the President and Members of the American Foundrymen's Association, Inc.

The secretary's report contained in Bound Volume of Transactions, No. XXIX, was for the period June 30, 1919, to Dec. 31, 1920, and included the auditor's report for that period.

The membership statistics contained in this report and the auditor's statement attached are for the fiscal year ending Dec. 31, 1921, supplemented by the treasurer's financial statement presented to the board of directors at the annual meeting of the board, Oct. 3, 1922.

The calendar year 1921 was the first year since the association was organized in 1896 in which no convention of the association was held. This was due to the fact that it was decided to return to the practice of holding spring meetings. The directors were unanimous in feeling that to make this change it was better to go over to the second spring following the last fall meeting in October, 1920, than to hold another convention and exhibit within an interval of only seven months. This was felt to be particularly advisable in face of the general business depression of that year.

Small Loss in Membership

In the following table giving complete data covering the membership of the association to Dec. 31, 1921, it will be noted that there is a net loss of 63 in membership, which is the first time that a loss has been recorded since 1916, when we experienced a net loss of 55. The loss of the past year can be quite properly attributed first, to the fact of no convention being held during the year, and second, because of many foundries going out of business or being temporarily closed down during the depression.

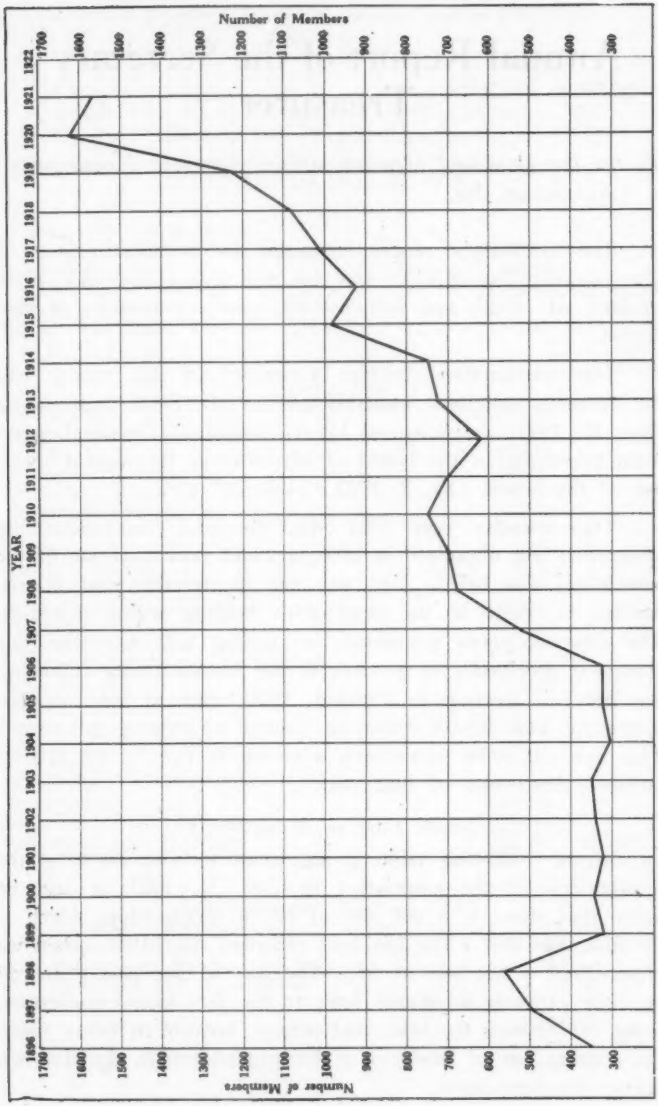

CHART SHOWING MEMBERSHIP OF AMERICAN FOUNDRYMEN'S ASSOCIATION, 1896-1921

Report of Membership on December 31, 1921

Active Members in good standing Dec. 31, 1920		1526
Active Members delinquent Dec. 31, 1920		90
Active Members on books Dec. 31, 1920		1616
Honorary Members		17
Total book membership Dec. 31, 1920		1633
Dropped—delinquent during 1921	38	
Resigned during 1921	54	
Mail returned	1	
Removed by death	2	95
		1538
New members during 1921		32
Book Membership Dec. 31, 1921		1570
Loss during 1921		63

A summary of association activities during the period under review will be found in President Bean's statement on page 1 and in the report of the board of directors.

Assistant Secretary

Acting upon instructions of the board of directors, the executive committee engaged Robert E. Kennedy of the University of Illinois, as assistant secretary. Mr. Kennedy did not take up active duties of the position until June 1, 1921, but for three months prior to that time he was engaged in preparing an extensive summary of the Bibliography on Molding Sands prepared by the National Research council for the joint committee on Molding Sand Research. Since his election he has served as chairman of the Committee on Papers and was in a large way responsible for the splendid technical program presented at the Rochester convention and which is recorded in these proceedings.

Necrology

Mention should be made in this report that the minutes record the death of three past presidents of the association and the adoption by the board of appropriate resolutions for each. On May 30, 1921, occurred the death of William Adrian Jones, president in 1901. On June 15, 1921, Joseph Sidney Seaman, president in 1900, died at his home in Pittsburgh. On Sept. 23, 1922, occurred the death of John P. Pero, president of

the association in 1917. A brief statement of the life and activities of these men was chronicled in the Bulletin, as was also the life and death of Henry Alden Carpenter, who, was a charter member, at one time vice president, for several years a director, and at the time of his death an active member of the executive committee on Molding Sand Research.

Finances

The auditor's report shows a cash balance on hand Dec. 31, 1921, of $748.97. The treasurer's report submitted to the directors at the annual board meeting, Oct. 3, showed total receipts for nine months of 1922, $17,711.70 and disbursements of $16,389.87, leaving a cash balance of $1,321.83; accounts receivable from dues, $1,806.00 and from the department of exhibits on account of appropriation voted, $2,000.00. A budget of estimated expenses for the balance of the year was submitted which, if not exceeded, will leave a cash balance on Dec. 31 of $454.84, not taking into account bills receivable on account of dues.

At this meeting it was voted to make the transfer of $2,000.00 from the department of exhibits, which has been previously ordered, from the earnings of the 1920 exhibit at Columbus, and it was further voted to appropriate $1,000.00 from the earnings of the exhibit at Rochester, and to contribute to the Institute of Metals Division of the A. I. M. E. the sum of $250.00.

These transfers of funds from the exhibit to the technical department for technical and research work make the total of appropriations, since the association assumed the management of exhibits, $8,000.00, and the total of contributions to the Institute of Metals Division of the A. I. M. E., $1,500.00. These sums plus $4,184.68, contributed towards the support of the War Service committee work of the A. F. A. make a grand total of $13,684.68 since 1916.

The treasurer's report also showed a balance in the special research fund of $1,722.32 made up of the following items: $252.79 being the balance of the Pangborn fund, $1,040.52 made up of the contribution of $1,000.00 from the National

Engineering Co. plus interest of $40.52, and $419.01 as the total of what is known as the Cleveland fund. The report showed that $2,237.21 of the original Pangborn fund of $2,500.00 had been spent in Molding Sand Research work, and it was unanimously voted by the directors to make the National Engineering fund of $1,040.52 immediately available for this work.

For the aid and support given him by President W. R. Bean, Vice President C. R. Messinger, Assistant Secretary Robert E. Kennedy, the board of directors, and all his assistants the secretary-treasurer extends his warm appreciation and sincere thanks.

Respectfully submitted,

C. E. HOYT, *Secretary-Treasurer.*

Auditor's Report for Technical Department

January 17, 1922

Mr. W. R. Bean,
President,
American Foundrymen's Association,
Chicago, Ill.

Dear Sir:—

I have audited the books of the technical department of the American Foundrymen's association for the year ending Dec. 31, 1921, and I certify that all recorded receipts have been deposited in bank, and all disbursements are supported by proper vouchers, and that the statements appended hereto are correct. Attached to this report are two statements as follows:

Statement of Receipts and Disbursements for the Year.

Trial Balance at Dec. 31, 1921.

Liberty bonds of an aggregate par value of $16,000 were shown to me, and constitute the following funds:

McFadden Fund	$ 5,000.00
Obermayer Fund	1,000.00
Seaman Fund	5,000.00
Whiting Fund	5,000.00
Total	$16,000.00

These funds have been increased during the year by the interest on the respective bonds. This interest has been deposited with the regular funds of the association. The Simpson fund of $1,000.00 received during the year is on savings deposit. The following transactions were had on the Pangborn fund:

Balance on hand Jan. 1, 1921	$2,512.50
Interest received	60.93
	$2,573.43
Less expended on Research Work	1,824.46
Balance on hand Dec. 31, 1921	$ 748.97

At Dec. 31, there was owing to the association for delinquent dues the sum of $1422.00 Furnishings were not depreciated at Dec. 31, 1921. This report does not embrace the transactions of the exhibit department, upon which I have reported separately.

Yours truly,

Robert T. Pritchard, *Chartered Accountant.*

AMERICAN FOUNDRYMEN'S ASSOCIATION

TECHNICAL DEPARTMENT

Statement of Receipts and Disbursements for Year 1921

RECEIPTS		
Dues		$17,737.90
Interest		118.23
Interest Standard Trust Savings Bank		23.66
Miscellaneous Receipts—Publications, etc.		822.96
		18,702.75
DISBURSEMENTS		
Auditing Expense	$ 276.25	
Committee Meetings Expense	2,227.36	
Convention Expense	323.75	
Discount and Exchange	84.05	
Due of Other Associations	67.00	
General Expense	105.48	
Office Expense	124.35	
Postage	1,017.09	
Publications	4,236.19	
Printing and Stationery	2,700.12	
Rent	544.00	
Salaries	4,300.00	
Stenographers and Clerical Help	2,148.95	
Telephone and Telegraph	101.11	18,255.70
Excess of Receipts over Disbursements		447.05
Trial Balance as at Dec. 31, 1921		
Harris Trust & Savings Bank	$ 295.25	
Superior Trust & Savings Bank, Cleveland	410.81	
Emblem Account	34.50	
Furniture and Fixtures	609.00	
Inventory of printed matter, etc.	855.58	
Loan to Exhibit Department	500.00	
Surplus		2,027.01
	2,705.14	2,027.01
Liberty Bonds	16,000.00	
Savings Account, Harris Trust & Savings Bank	748.97	
Savings Account, Harris Trust & Savings Bank	1,025.15	
Trust Funds:		
McFadden Fund		5,212.50
Simpson Fund		1,025.15
Pangborn Fund		748.97
Obermayer Fund		1,040.63
Seaman Fund		5,212.50
Whiting Fund		5,212.50
	20,479.26	20,479.26

Destruction and Reconstruction of French Foundries*

The Foundrymen's Technical Association of France (Association Technique de Fonderie) which had a membership of 400 before 1914, had its activities interrupted by the great war. After the reception of A. O. Backert, president of the American Foundrymen's Association in May 1919, it resolved to resume its work and since October 1920 its meetings have taken place regularly.

A permanent secretariate has been formed, and the members number at present about 200.

The committee of the Foundrymen's Technical Association is constituted as follows:

President:

M. RAMAS, Director of the French Metallurgical Company (Societe Francaise Metallurgique). Griffen process, of Gorcy (Meurthe et Moselle), 2 Rue de Constantinople, Paris, 8.

Chief Vice-president:

M. DAMOUR, Director of the Bayard and Saint-Dizier Foundries at Bayard (Haute-Marne).

Vice-presidents:

M. Jules CURY, Foundryman, Deville (Ardennes).

M. CHAPPEE, Foundryman, Mans (Sarthe).

M. DE BOISGROLLIER, Director of the Mazieres Foundries (Cher).

M. HELLER, 12, Rue de Madrid, Paris, 8.

M. MASSON, Managing Director of Mechanique Moderne, 9, Lobeau, Nancy (Meurthe et Moselle).

M. RIVIERE, Foundryman, Quimperle (Finistere).

M. SANDRE, Manager of the Societe du Perigord, 43, Rue de Clichy, Paris, 9.

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*Communication presented by the Foundrymen's Technical Association of France.

M. THOMAS, Manager of the Etablissements Piat, 19, Avenue de la Gare, Soissons (Aisne).

General Secretary:

M. Camille DIDIER, Director of "La FONDERIE MODERNE", 145, Faubourg Saint Denis, Paris, 10.

Treasurer:

M. RONCERAY, Engineer (Arts et Metiers), Deputy Administrator of the Etablissements Bonvillian et Ronceray, 5, Rue Paul Carle, Choisy-le-Roi (Seine).

Members of the Committee:

M. AUBRY, Manager of the Brousseval blast furnaces, Brousseval (Haute-Marne).

M. BERMOND, Foundryman, Dole (Jura).

M. Jules COCARD, Director of the Societe des Etablissements Cocard, 42, Rue de Valenciennes, Lille (Nord).

M. DECOLLOGNE, Malleable Iron-founder, Pont-Audemer (Eure).

M. DE FLEURY, Industrial engineer, 18, Avenue Gambetta, Choisy-le-Roi (Seine).

M. BERDINGER, 86, Avenue de la Republique, Paris, 11.

M. EISSEN PIAT, 85, Rue Saint-Maur, Paris, 11.

M. GARAND, Manager of the Etablissements Chavanne Brun, 56, Rue Lafitte, Paris, 9.

M. GOSSE, Engineer of the Societe Senelle-Maubeuge, Maubeuge (Nord).

M. LAMBERTON, Engineer, 5, Rue Antoine-Arnauld, Paris.

M. LARDIN, President of the Amical et Mutuelle de Fonderie, 91 bis, Rue Manin, Paris, 19.

M. LEBEL, Foundryman, 295, Rue du Faubourg de Hem, Amiens (Somme).

M. MONTUPET, Foundryman, 11, Boulevard Lannes, Paris, 16.

M. PORTEVIN, Lecturer at the Ecole Centrale, 75, Rue de Passy, Paris, 16.

M. REVEILLON, Copper founder, 95, Avenue de la Republique, Bagnolet (Seine).

M. THUAU, Foundryman, Rennes (Ille et Vilaine).

Vice-presidents abroad:
M. VANZETTI, (Italy).
M. HEGI, (Switzerland).
M. BRASSEUR, (Luxembourg).
M. LEONARD, President of the Association Technique de Fonderie (Foundrymen's Technical Association) of Liege, 51, Quai du Canal, Herstal (Belgium).

As examples for showing the extent of the damage done to French foundries by the Germans we have specially chosen foundries on the line of the front or in its neighborhood.

It has not been our desire to recapitulate the examples of remarkable vitality provided by the great metallurgical works, but, although of a more modest nature, we have rather chosen to describe the patient and laborious, unremitting and tenacious efforts put forth by foundrymen whose works are of moderate and average extent in order to recover their pre-war manufacturing status.

General Character of Destruction

Before describing a few of these works we think it well to give some indication of the characteristic destruction which has been wrought in almost all the foundries.

Apart from the havoc caused by bombardment or the direct facts of war, the Germans subjected the factories to pillage.

The iron flasks were systematically smashed and used as scrap for melting. Many of them were despatched to Germany to be used in the manufacture of projectiles and other material of war. All the patterns were sent away or have disappeared. Many were used as fuel, while others were left exposed to the damp and the weather; this was in order that the French foundrymen might be prevented from resuming their production quickly on their return. The primary metal patterns as well as the pattern plates were remelted; bronze patterns were particularly sought after.

It has been necessary in all the foundries of the liberated territories to make fresh patterns as well as fresh designs and pattern plates.

In the Ardennes district especially we may draw attention to the disappearance of very old patterns of ornamental pieces, of heating apparatus, etc., representing a very considerable amount of capital. This is a loss which cannot be estimated and it applies to almost every one of the foundries. We would point out also that the designs and studies were taken away and the factory plans destroyed. The works plans relating to material special to any particular factory were carried off, and this notwithstanding the objections made by the foundrymen or their representatives who had remained during the invasion to safeguard their property.

As a general rule the Germans removed the administrative documents and the business books, which made it difficult to make an exact valuation of the property carried off by them and of the havoc done in the foundries and their dependencies.

Special materials such as bronze and aluminum forming part of the various foundry machines were removed, most of this material being sent to Germany. It may be noted that it was not only the French machinery that suffered this fate, but that even German machinery recently sold to French manufacturers was sent back across the Rhine. When a machine was not in good working order it was completely broken up; the copper and aluminum were removed and the rest ot the machine rendered unusable.

Certain foundries which were stripped of their material—patterns, pattern plates, molding machines, hoisting equipment (engine-driven and hand travelers, jib and other cranes), ventilators—even had their cupolas dismantled and removed in order to be sent to Germany. In order to regularize these seizures of machinery the Germans promised to issue in return requisition vouchers. Many foundrymen thus plundered never received any vouchers, and those who did receive them had difficulty in obtaining them.

To these seizures must be added the complete destruction of the power houses—boilers and steam engines, alternators, compressors, hydraulic accumulators, etc. Several foundries were not stripped at first but were used by the Germans for their own requirements. After the dismissal of the French

management staff who had remained at their posts the manufacture of shells and bombs was carried on by the Germans with the help of all the materials they found at hand.

Other foundries were transformed into stores and for this purpose had their ground floors paved and cemented, while others were turned into automobile garages or into stables. As the German cavalry suffered greatly from veterinary diseases it was necessary, in order to prevent the propagation of contagious maladies (a good many cases of tetanus occurred and even caused death among men), to have the premises disinfected. This was sometimes costly owing to the extent of the contaminated surfaces.

Restoration Difficult

In certain foundries the Germans had constructed concrete shelters for protection against bombardments. These were so thick that it would have been very difficult and, particularly, very costly to get them removed. The foundrymen have ingeniously utilized them for storing pattern plates and patterns, which were thus secured against all danger of fire.

We should like to make special mention of the arduous and unremitting efforts put forth by the manufacturers at a time when as yet they were without any financial help. They began with the clearing of their works, which proved a formidable task. With the small amount of material to be got on the spot, and without waiting, they endeavored to get their foundries going again. Aided later on by the French government they continued the work which they had already begun with their own resources.

They carried out repairs wherever possible; they rebuilt in the vicinity or elsewhere. They afterwards secured material, often at high prices, for at that time materials were scarce, and builders could not at all meet the great demands made upon them.

After two years we are in a position to say that all the foundries without exception have resumed their pre-war work. They have nearly all done so, however, on a small scale, with inadequate resources and only turning out a portion of their

former products owing to the insufficiency of the financial means placed at their disposal as compared with the war losses suffered by them.

In the following documents it has been our aim to select separate examples distributed over the zone of the front in order to show that these are not special cases but representative examples which might be reproduced in very large numbers. One cannot but admire the persistence and determination of these manufacturers who in two years have reinstalled

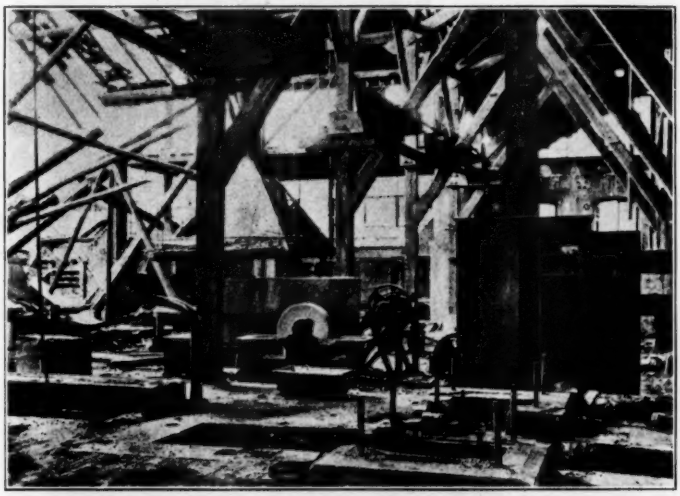

FIG. 1—INTERIOR OF A REPAIR SHOP AT PONT A MOUSSON PLANT, SHOWING FOUNDATIONS FROM WHICH MACHINES WERE REMOVED BY THE GERMANS

their works and reconstituted their collection of patterns and pattern plates, and who for the most part have furnished a liberal contribution towards the reconstruction of industries in the liberated territories which had suffered the same fate as themselves.

Below we take up in detail and show by illustrations from photographs the extent of actual damage which was done to

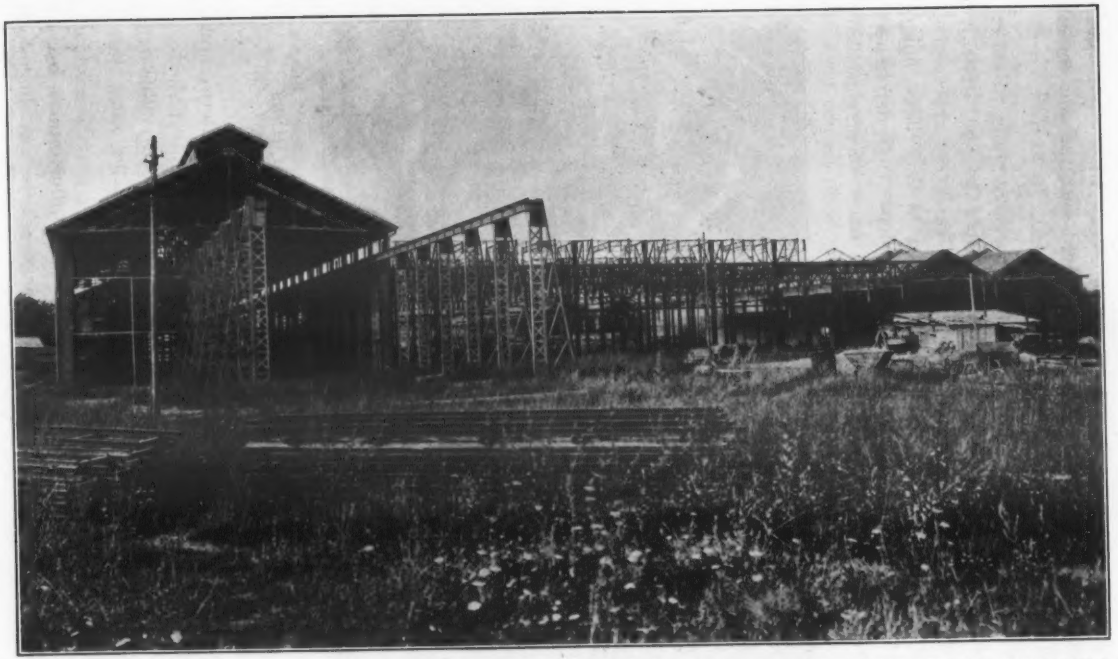

FIG. 2—NEW FOUNDRY OF THE PONT A MOUSSON COMPANY AS IT APPEARED IN COURSE OF CONSTRUCTION, AUG. 18, 1920

various foundries and the progress which has been made in restoring these plants.

PONT A MOUSSON BLAST FURNACE COMPANY
(*Societe des Hauts Fourneaux de Pont a Mousson*)

One of the foremost manufacturers is the Pont a Mousson Blast Furnace Co. whose extensive works extend over a large area at Pont a Mousson in the eastern part of France. It is necessary to note all the protective steps taken by it for the purpose of trying to ensure the best possible supply of material so as to be in a position to resume its normal working. The Pont a Mousson Blast Furnace Co., which possesses a world-wide reputation for the construction of cast-iron pipe and fittings did not have its works at Pont a Mousson overrun, but they were as near the lines as one to two kilometers so that the Germans bombarded them daily.

Before the war five blast furnaces produced together 300 tons of pig iron per 24 hours. There were also several foundries equipped with cupolas and also arranged to cast directly from the blast furnaces. To feed the blast furnaces the company had installed coke ovens, the construction of which had been begun. There were various special workshops for screw cutting, tap making, pump castings, cementation and briquetting.

Fig. 1 shows the interior of the repairing shop, indicating the engines raised and the foundation bolts projecting from the concrete work. Fig. 2 shows a stage of reconstruction on a new site. This photograph was taken on August 18, 1921. In Fig. 3, which shows the second fusion foundry completely finished on August 4, 1921, we already see the stocks of pipes beginning to accumulate.

Fig. 4 gives a view of the pipe park in 1914; some of the shops on the second fusion foundry can be seen. This view was taken from the dump on the works. We cannot too strongly emphasize the observations made by Monsieur Camille Cavallier, president of the administrative council of this company, with regard to the material ravages committed: (1) the direct damage which, however, represents a considerable sum,

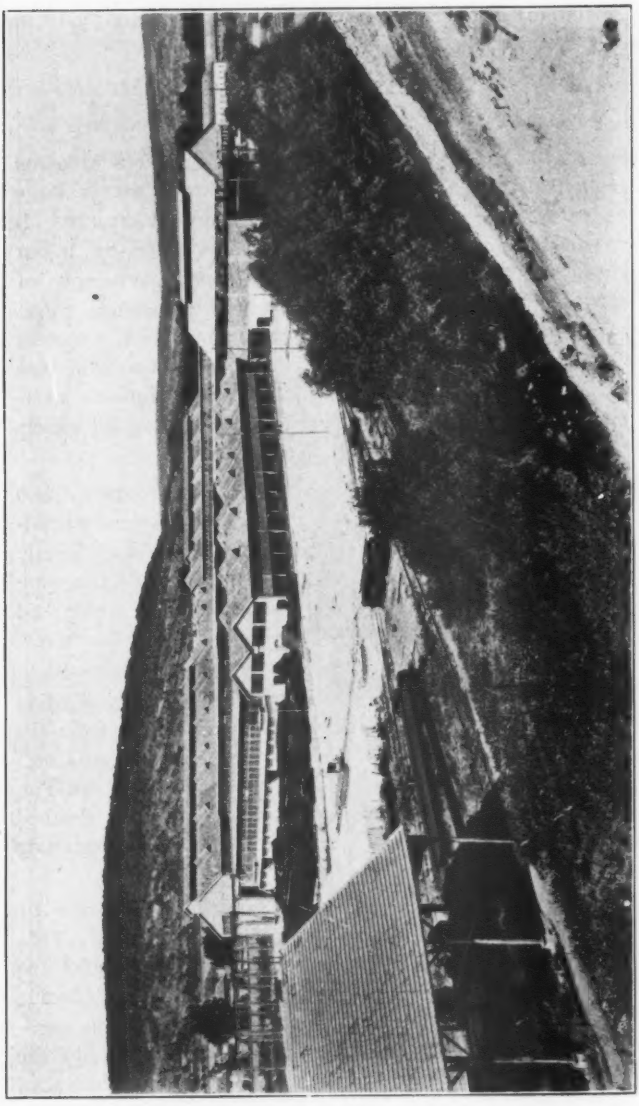

FIG. 3—A FOUNDRY UNIT OF THE PONT A MOUSSON COMPANY AS IT APPEARED AUG. 4, 1921, SOON AFTER COMPLETION

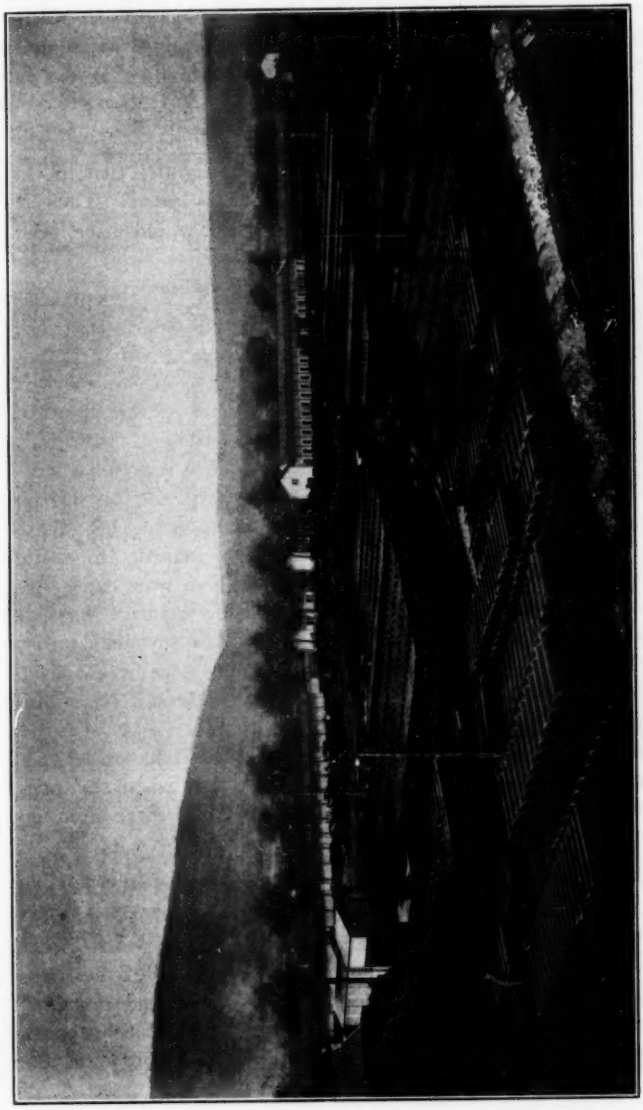

FIG. 4.—THE PIPE PART AT THE PONT A MOUSSON WORKS IN 1914, BEFORE THE BEGINNING OF HOSTILITIES

and (2) the indirect damage to the incalculable nature of which, owing to the unbroken development of the company's foundries, M. Cavallier specially drew the shareholders' attention in 1920. We quote his words:

"The figures show in fact that the volume of our production was increasing each year by one-eighth; that is to say we were doubling our output every six years. Thus if there had been no war our output in 1920 would have been double what it was in July 1914.

"After 15 months of arduous labour we were producing only one-fifteenth of our 1914 output! But this is not all: about 1926 we may perhaps have reached our pre-war output figures. These figures, however, will not be one quarter of what they ought to have been in 1926 had there been no war. In six years the Pont a Mousson Company, owing to the war, will have only one-fourth of the output which it would otherwise have had. Who can estimate this loss, a loss which strikes the most progressive and enterprising concerns—those which reduced their dividends to a minimum in order to create national wealth and taxable material? When war came, we were going at full capacity. Our productive capacity was increasing by one-eighth every year; that is to say that today, in 1920, our productive capacity, but for the war, would have been double what it was in 1914. In 1926 it would have been double the 1920 figure, or four times that of 1914. Instead of this our productive capacity in January 1920 was one-fifteenth of what it was before the war, that is to say one-thirtieth of what it would have been today had there been no war.

"Does not this figure give a striking idea of the terrible loss which the war has imposed upon us apart from such direct damage as is covered by the Reparations Law? * * * "

After the armistice, on the sudden stoppage of the production of material of war, those factories which had remained working were transformed for the purposes of peace requirements, and in addition steps were taken to reconstitute the Pont a Mousson factory and the relief works at Auboue.

At Pont a Mousson a manager was appointed, engineers were placed under him, workmen returned gradually, and this entire staff got to work. The rubbish was removed, the motors were released from the carapace of sand-bags with which they had been covered, roofs were rebuilt—in short everyone worked strenuously, so that by April 1919 it was possible to put a cupola furnace in commission for supplying some of the shops of the flat work foundry. The output was very small, but was increased as the work of restoration progressed. Then in

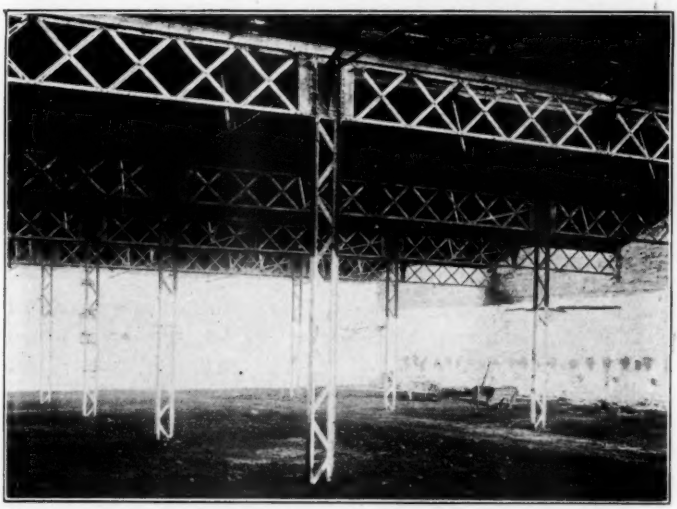

FIG. 5—INTERIOR OF THE OLIZY FOUNDRY, AS IT APPEARED AFTER THE DEPARTURE OF THE GERMANS

August 1919 the top-cast pipe foundry was started. So far, however, the progress made was merely tentative, and until the blast furnaces could be blown in the works could not be said to have recovered any real vitality.

In accomplishing this enormous difficulties were encountered. The repair of the blast furnaces had been pushed on rapidly, but what took most time was the restoration of the electric plant which, as we have clearly said, had suffered serious injury.

OLIZY FOUNDRY

(Meuse)

This foundry, belonging to the old establishment of Branchet, Richard & Co., who have their head office in Paris and a branch at Lyons, made a specialty of kitchen apparatus and gas heating apparatus for factories using gas power. It also manufactured cast iron baths and all sorts of sanitary and hygienic appliances in the same metal.

We give an illustration in Fig. 5 showing what was left in the foundry after the departure of the Germans.

THE PERBAL FOUNDRY

Charency Vezin

Before the war this foundry specialized in iron founding for stoves and other heating apparatus and in enameled goods which were very well known. It comprised several molding shops.

The power was supplied by an hydraulic turbine, two steam engines and one vane wheel for the preparation of sand molds. An electrical power house supplied light for the factories and to Charency-Vezin and Epiez. There were 400 tons of flasks, an enormous collection of special patterns, machine and hand molding plant, and a rail track 650 meters in length serving the flask park and all the factory out-buildings.

The output of finished goods was 2,400 tons annually, a stock of 550,000 kilograms being kept to cover the immediate requirements of customers.

Such was the condition of this prosperous establishment on the eve of the war. What it is today Monsieur G. Perbal, its energetic proprietor, will himself inform us:

"When I regained possession of my factories in April 1919 I found the enameling shop with its furnace and several buildings entirely demolished. Of the whole equipment there remained only the turbine, the two cupola furnaces and the electrical power house, all of which were in a very bad condition. Flasks, patterns and miscellaneous stores had all been carried off by the Germans.

"With the active help of the Office of Industrial Reconstruction and with the aid of State advances I was able to re-

install such equipment as was most indispensable and resumed casting on October 1, 1919. My staff of employees and workmen, which in 1914 numbered about 200 persons, at present exceeds that number.

"Moreover, while I have proceeded simultaneously with the normal development of the business and the restoration

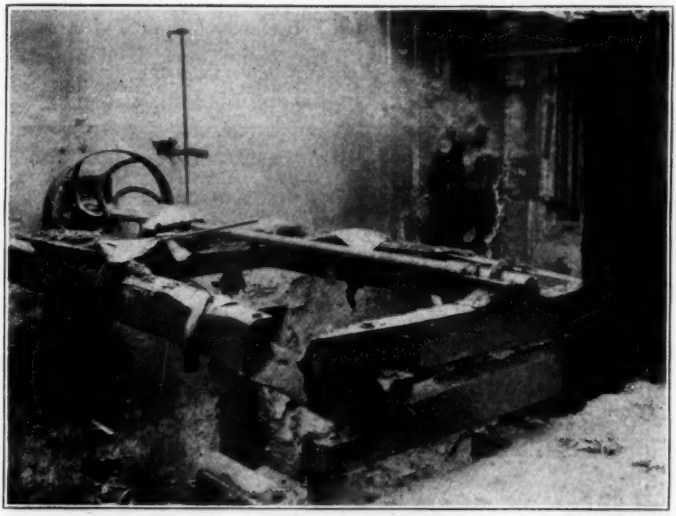

FIG. 6—DEBRIS OF A SAND GRINDING MACHINE IN THE PERBAL FOUNDRY

of my stock of flasks and patterns, my present output of finished castings exceeds that of July 1914. Finally, I am about to start an enameling shop which has been newly built and to install electric power, for which purpose the station for transforming the current from high to low tension is in course of being installed."

Fig. 6 shows the debris of a sand-grinding machine, one of the stones of the grinder being seen on the ground. Fig. 7 shows the state of the machine molding foundry, the machine molding shop having been restored. A photograph which we

were unable to obtain showed the same molding shop transformed into a stable with the horses' cribs visible.

THE FOUNDRY OF THE GUISE CO-OPERATIVE SOCIETY

(*Les Ateliers de Fonderie de la Societe du Familistere de Guise Colin & Co. a Guise, Aisne*)

Before the war the foundry of the Co-operative Co. of Guise occupied an area of about 3 hectares (about 7¼ acres), or approximately one-fourth of the entire area of the Guise works and one-half of the area built upon. Their dependencies

FIG. 7—A CORNER OF THE PERBAL FOUNDRY RESTORED FOR USE

(pattern and flask stores, sand and coke sheds, castings park) occupy about 8,000 square meters of this area.

The workshops were divided into five groups, each served by two cupolas each working every other day.

Foundry No. 2, in which, in addition to the hand molding machines, the two large machine molding batteries were installed, was supplied by 4 cupolas.

There were thus 14 cupolas in all working alternately, or six working together. In the years before the war they

produced annually 16,000 tons of good castings. This is a considerable quantity in view of the variety of the articles produced and their relatively light weight.

At the moment of mobilization the Guise factory employed about 650 molders who had at their disposal a considerable amount of material: 50,000 wooden flasks of all sizes, as many metal flasks, over 4,000 manufacturing patterns in cast metal not including the zinc standards (of considerable value since they represented more than fifty years' labour), which were carefully labeled and entirely occupied a large two-storied building. These figures do not include the special flasks and patterns employed for the machine molding batteries, of which mention will be made later.

Independently of the hand molding in which the majority of the staff were employed, the factory had adapted the various improvements effected in foundry work to its own manufacturing requirements. Thus a large number of molding presses, both hand and hydraulic, were installed. Their construction and working principle, however, merely resembled, though on a smaller scale, a system of molding by intensive production which had been inaugurated in the company's factories as long ago as 1875. We allude to machine molding, and we would draw attention to some little length to the details of this unique installation of its kind, which unfortunately the Germans entirely destroyed.

The machine molding shop was constituted in two distinct groups each of which formed, so to speak, a complete molding cycle.

Each of these groups of batteries consisted of four large horizontal turning tables about 5 meters in diameter.

Of this magnificent plant, there remains nothing, absolutely nothing, except the damaged walls and the ruined roof.

Only a few patterns have been left of a most valuable collection indispensable to the working of the machine molding plant. All the others were smashed and carried off by the enemy.

The large foundry shops were turned into stables. The cupolas were pillaged and rendered useless, the blowers dis-

mantled, and every one of the 50,000 wooden flasks burnt. A few metal flasks were left, but in the form of scrap.

The wonderful collection of zinc standards which formed a considerable portion of the company's industrial assets, was destroyed.

The staff, animated by an enlightened and energetic instinct, returned in large numbers after the armistice and soon succeeded in getting the shops into condition for resuming work. On March 5, 1919, the copper foundry furnaces were restart-

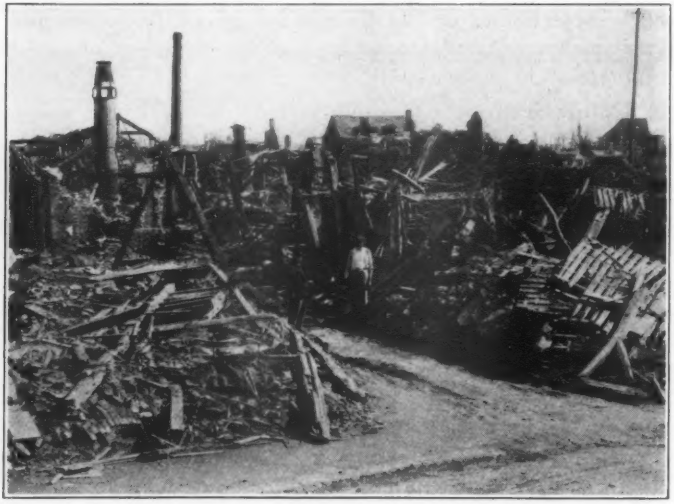

FIG. 8—RUINS OF THE PLANT OF GUILLEMIN, SERGOT & PEGARD

ed. On August 16, 1919, the first cupola was relighted, and the work of manufacture was actually resumed with the few patterns which it had been found possible to reconstruct.

The works gradually became more and more busy, satisfying their clients' requirements to the best of their ability. At present 400 molders have sufficient material and patterns to work with, and the factory has recovered its pre-war activity. Five cupolas are at work, producing an average of 30 tons of good castings per day, a figure which exceeds half that for 1914.

The hand molding presses have been reinstalled and new hydraulic presses are at work. Jar-ramming machines, the last creation in foundry work, will presently add their production to the general output. The installation of the great machine molding plant, which involves considerable engineering work, will alone take a considerable time to carry out.

SURVEY OF THE WORKS OF GUILLEMIN, SERGOT & PEGARD. (Amalgamated)

(*Les Ateliers Guillemin Sergot & Pegard Reunis*)

The Guillemin, Sergot & Pegard (Amalgamated) Company was formed before the war by the combination of the two factories, viz. that of M. Guillemin, machine tool manufacturers, of Albert, and that of MM. Sergot & Pegard, also machine tool manufacturers of the same town.

As a result of the first German advance in 1914 the two factories were demolished. After an interval of a year, the front having been stabilized in the vicinity of Albert, the company decided to take up its quarters in an omnibus depot in Paris in order to continue its work and make its contribution to the National Defence.

In May 1917, owing to the advance made by the allied troops on the Somme, the company repaired and restored one of its factories at Albert. For its supply the Charles foundry, which for more than two years had suffered damage by successive bombardments, was acquired. This foundry was reconstructed and started working in November 1917. It produced 60 tons of castings per month, with one cupola and three hand travelers of 3, 6 and 10 tons.

From November 1917 to May 1918 the factory and foundry worked normally and turned out three to four planing machines, and this 38 kilometers from the battle line. On March 21, 1919, the day of the German offensive on the Somme, the town of Albert was bombarded by aircraft and the foundry was greatly damaged.

When the second invasion took place the works were completely demolished and despoiled of their material so that after the armistice nothing was left but ruins.

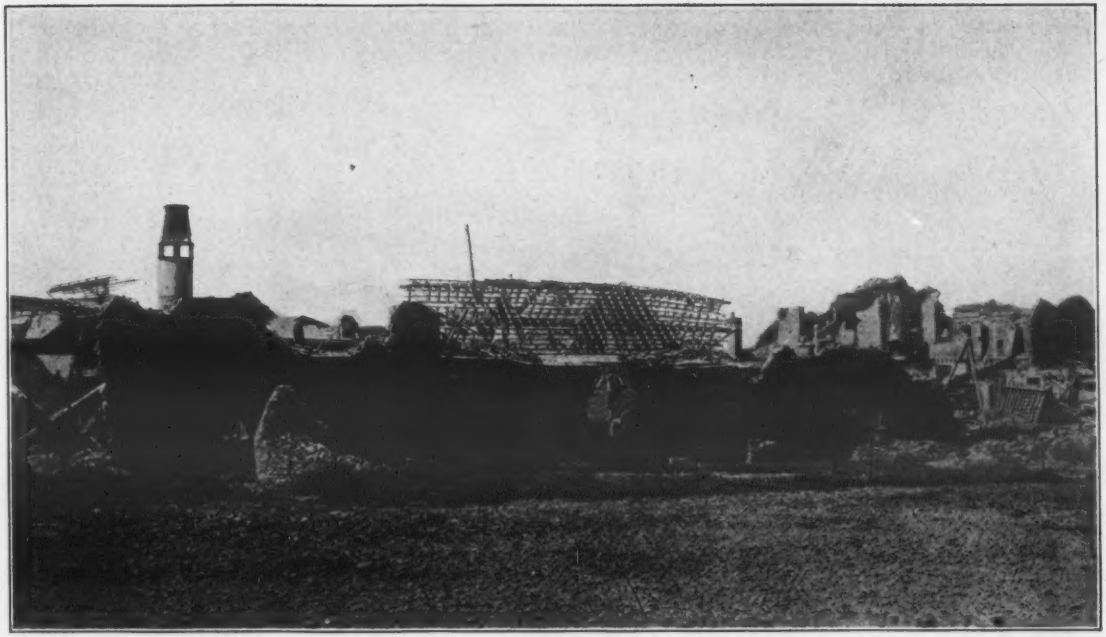

FIG. 9—ANOTHER VIEW OF THE WRECKED FOUNDRY OF GUILLEMIN, SERGOT & PEGARD, NEAR THE TOWN OF ALBERT

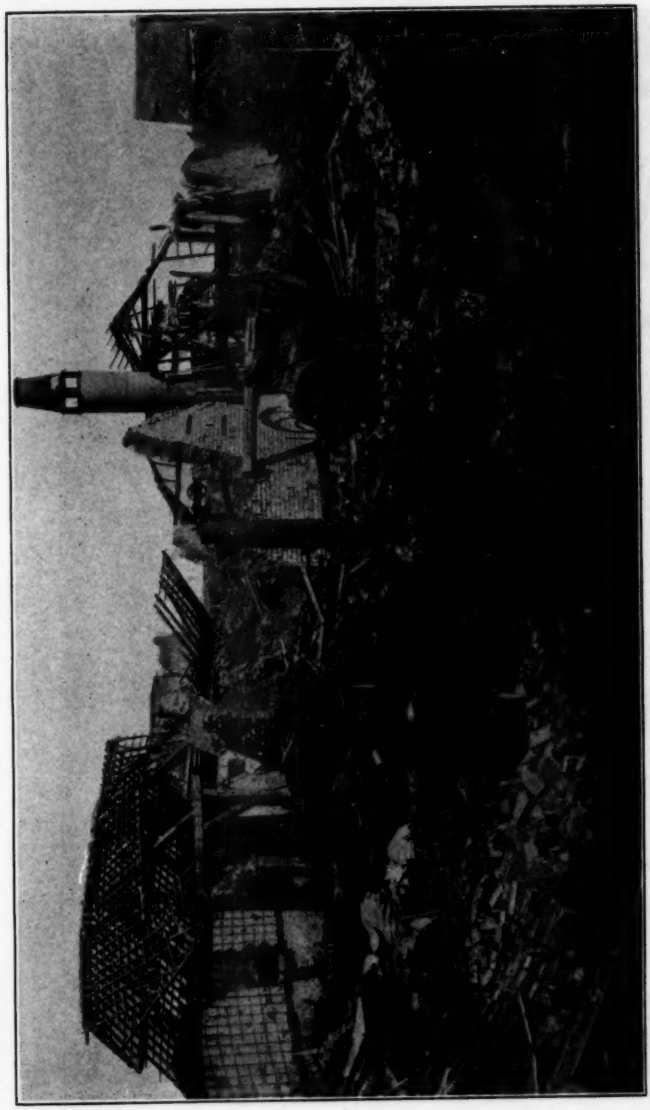

FIG. 10—REMAINS OF POWER HOUSE. THE BOILER HAD BEEN INSTALLED AFTER THE PLANT WAS LIBERATED BY THE ALLIED OFFENSIVE OF MAY, 1917

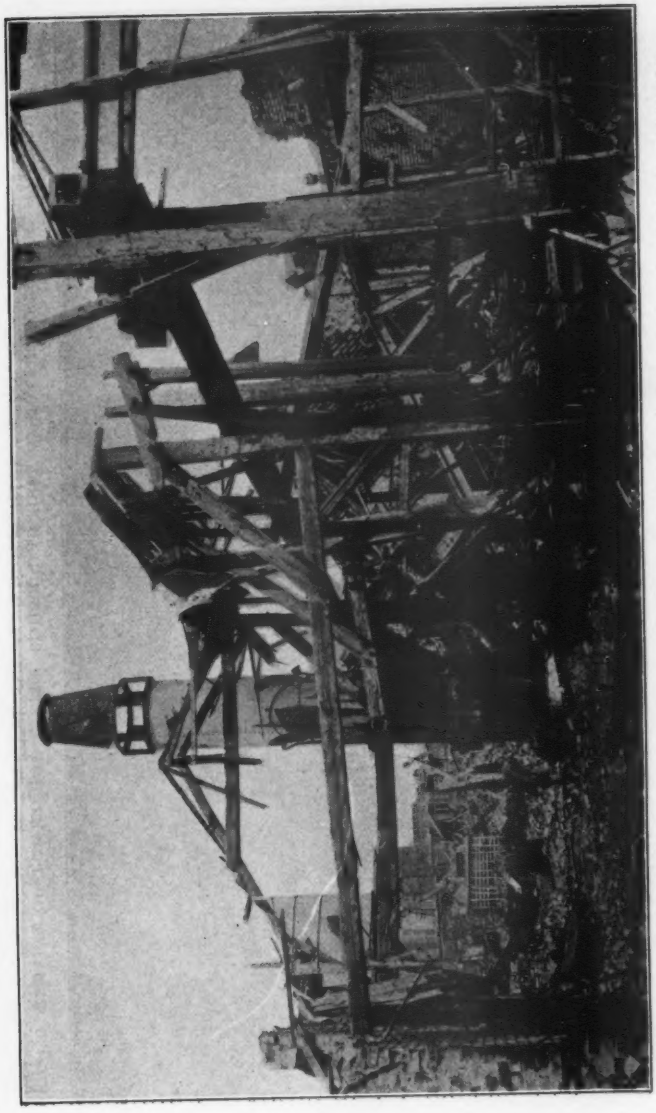

FIG. 11—ANOTHER VIEW OF THE RUINS OF THE GUILLEMIN, SERGOT & PEGARD FOUNDRY

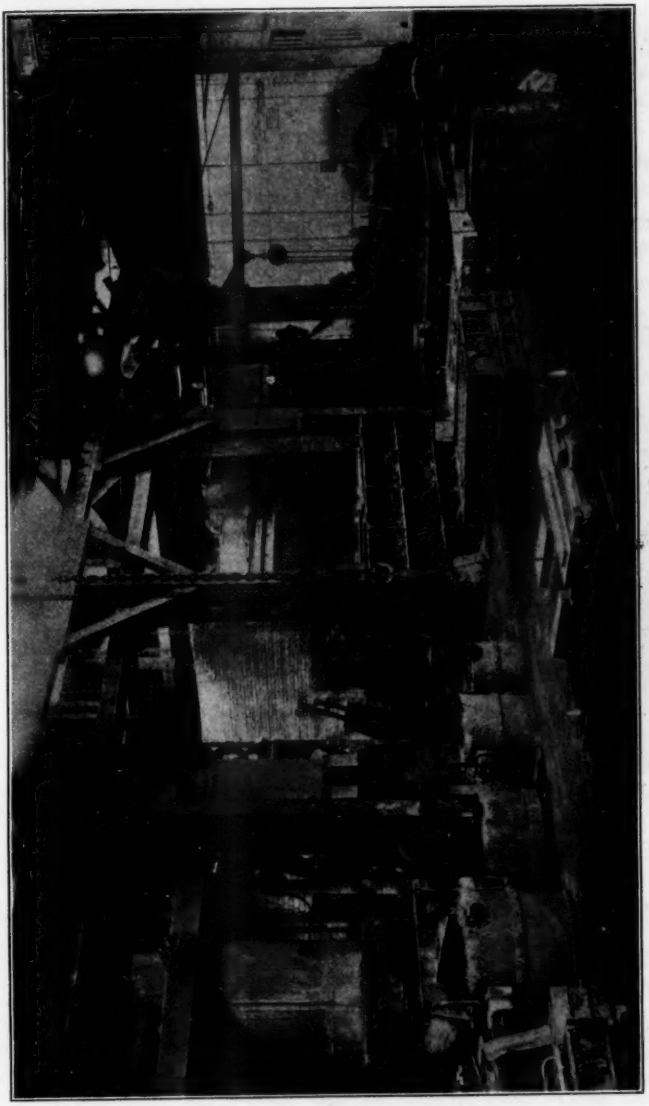

FIG. 12—THE GUILLEMIN, SERGOT & PEGARD COMPANY REMODELED A CHEMICAL FACTORY AND NOW USES IT AS A FOUNDRY

Fig. 8 shows the foundry seen from the Rue Felix Faure. Fig. 9 shows what remained of the foundry seen from the Rue Thiers. Fig. 10 shows what remained of the power house boiler installed in 1917.

Fig. 11 shows the foundry seen from the courtyard behind the factory.

Meanwhile the energy of M. Pegard, who was desirous of executing the numerous orders he had received, enabled him to install a foundry and fitting shop in an old chemical factory belonging to the Saint Gobain Co. This new plant at Chamiers

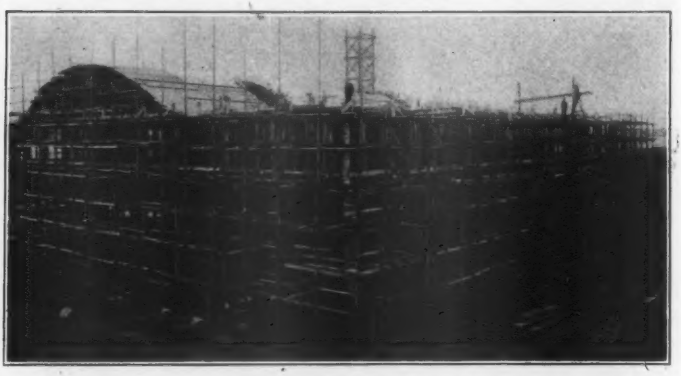

FIG. 13—A VIEW OF CONSTRUCTION WORK AT A PLANT OF LES FILS DE PIAT & CO.

near Perigueux supplemented the works in the Boulevard de la Villotte in Paris, which was also developed to meet the ever-growing requirements.

Fig. 12 shows a part of the changes which were found necessary—the construction of independent column supports for the overhead tracks, one traveler of 10 tons and one of 6 tons. The Perigueux works are connected with the railway and the navigable river in the neighborhood.

It may be noted that M. Pegard formed a section of apprentice molders at his Perigueux factory. This is still in existence and has supplied the company with excellent molders.

The Perigueux foundry produces at present, working at reduced capacity, 60 to 80 tons of castings per month.

THE BIACHE SAINT VAAST WORKS

Before the war these works were specially engaged in the treatment of non-ferrous metals, such as copper, bronze, brass, nickel, aluminum, zinc, tin and metals for coinage purposes.

There was also a plant for the manufacture of copper, brass and steel tubes. These were made either welded or seam-

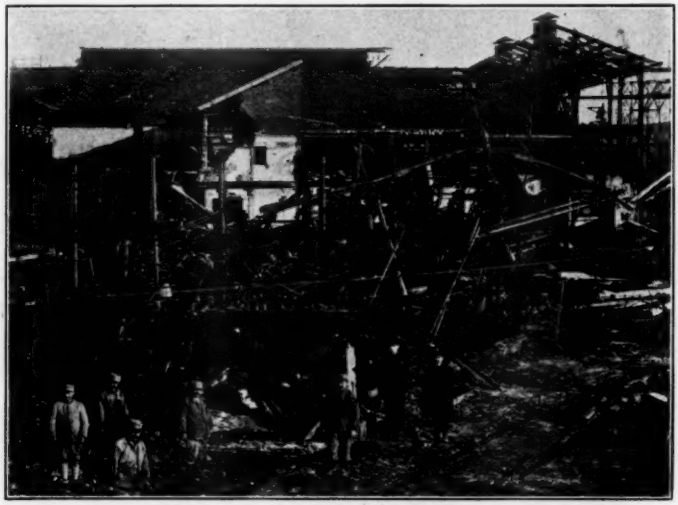

FIG. 14—SCENE OF DESTRUCTION AT WORKS OF LES FILS DE PIAT & CO. IN SOISSONS

less, which necessitates intricate and delicate plant. These works are in course of being rebuilt.

The Board anticipates that the works will be unable to resume their normal operations for at least two or three years. Owing to the extent of the damage done it has been impossible to rebuild all departments of the works on the same site; the company is taking advantage of their total destruction to equip its factories in a thoroughly up-to-date manner.

We have just learned that the Biache Saint Vaast found-

ries have recently been started again, thus anticipating the reconstruction of the entire establishment.

THE FOUNDRIES AND ENGINEERING WORKS OF PIAT, SONS & CO. (Les Fils de Piat & Co.)

This company enjoyed a world-wide reputation for the manufacture of transmission gearing. At its Magdeleine factories in Soissons it cast gear wheels of all sizes and weights.

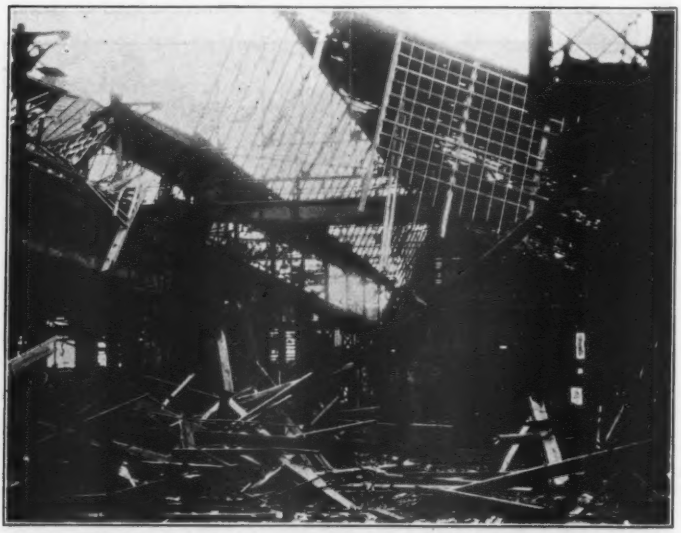

FIG. 15—CONDITION OF PIAT FOUNDRY AT END OF WAR

It made a specialty of gear castings for use straight from the foundry. The Piat works are replacing their factories which were destroyed by a modern foundry on the semi-continuous plan. The reconstruction programme will be completed towards the end of 1922, and the minimum output in future will be 100 tons per day.

In August 1914 the factory had a staff of 600 workpeople and employees. The daily output was 30 tons of machinery castings, transmission gearing and central heating apparatus. The buildings covered an area of 16,240 square meters.

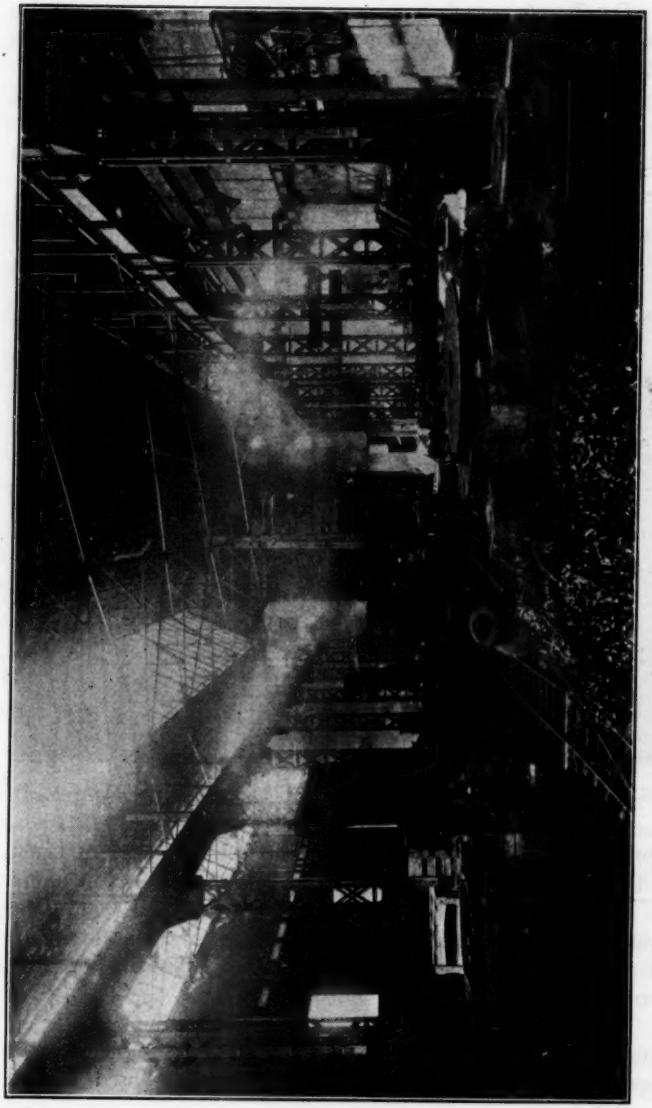

FIG. 16—THE FOUNDRY SHOWN IN FIG. 15 AS IT APPEARED AFTER RESTORATION

The foundry workshops, equipped with 4 cupolas and 10 traveling cranes, had also a pattern shop with a pattern store and laboratory.

The machine shops and stores were served by 12 traveling cranes and were equipped with about 100 machine tools; a system of standard gauge tracks connected all buildings. The

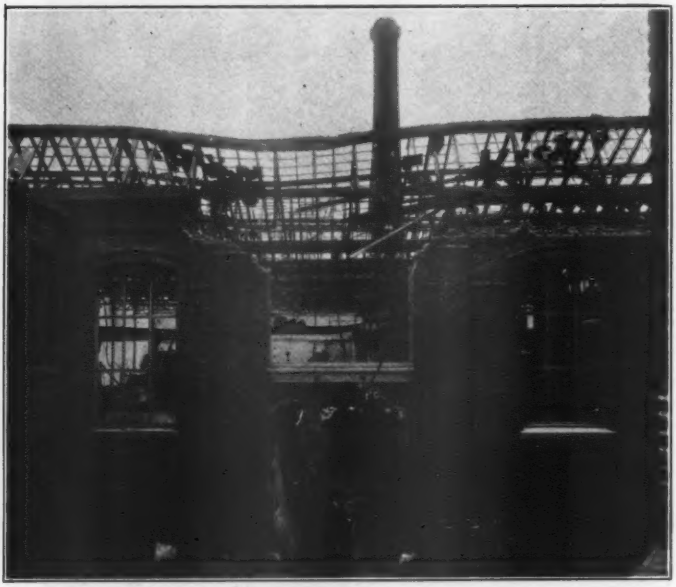

FIG. 17—ENTRANCE TO THE FOUNDRY OF THE JULES COCARD CO., LILLE

power was supplied by a steam plant of 350 horsepower and a Dowson gas plant of 200 horsepower.

Fig. 15 shows the condition in which the foundry was found. To the right in the background two cupolas can still be seen standing upright with their automatic charging platform.

As it was found possible to repair a portion of the old foundry buildings, this is at present working, supplied by 3 cupolas. The daily output is 3 tons, which is used for the

requirements of the works themselves. Fig. 16 shows this shop after its restoration.

The pattern shop, the steam power house and the machine shops have been rebuilt, as well as the office buildings, (8,325 square meters). The shops were rebuilt or restored after 1920 and are now working. The works employ 150 men and women.

FIG. 18—A CORNER OF THE COCARD FOUNDRY SHOWING THE MASS OF DEBRIS

New foundry buildings covering 4,830 square meters are in course of construction. This foundry will be supplied with six cupolas and thoroughly up-to-date equipment. It is expected to be completed by the end of 1922. It will be a semi-continuous foundry on several floors, and the directorate are giving its construction their closest attention.

The standard gauge track system has been reconstructed, and already the first steam engine has been installed in the power house and supplied the works with 450 horsepower.

THE JULES COCARD CO., LILLE

(*Societe Anonyme Jules Cocard*)

This company, in the department of the Nord, used to

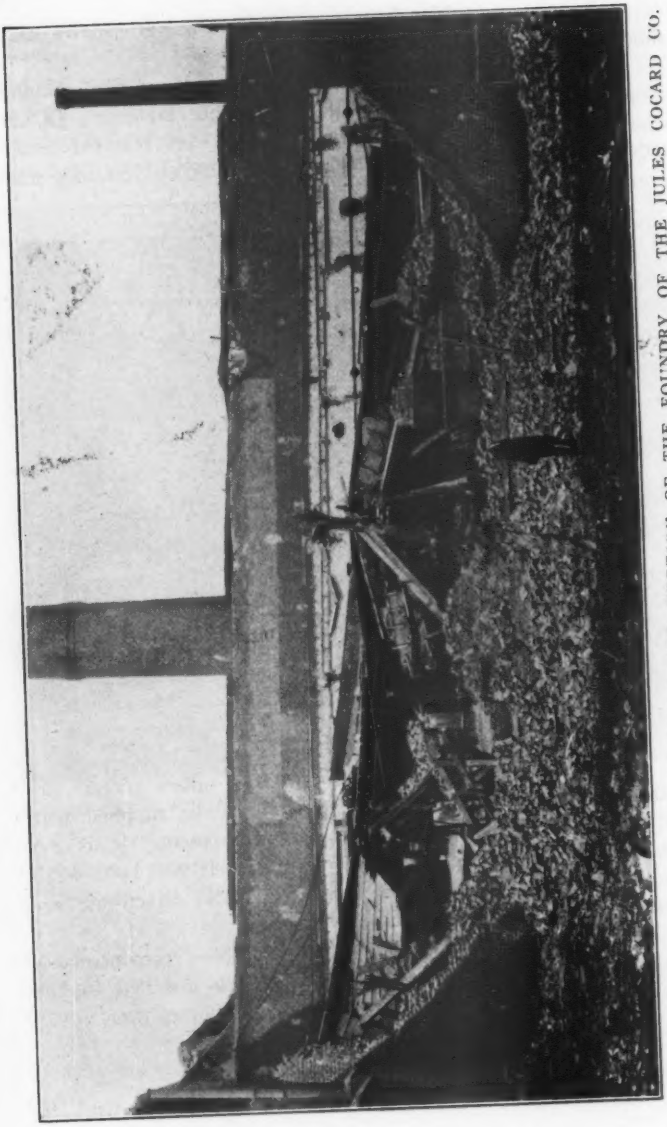

FIG. 19—ANOTHER VIEW OF THE DESTROYED PORTION OF THE FOUNDRY OF THE JULES COCARD CO.

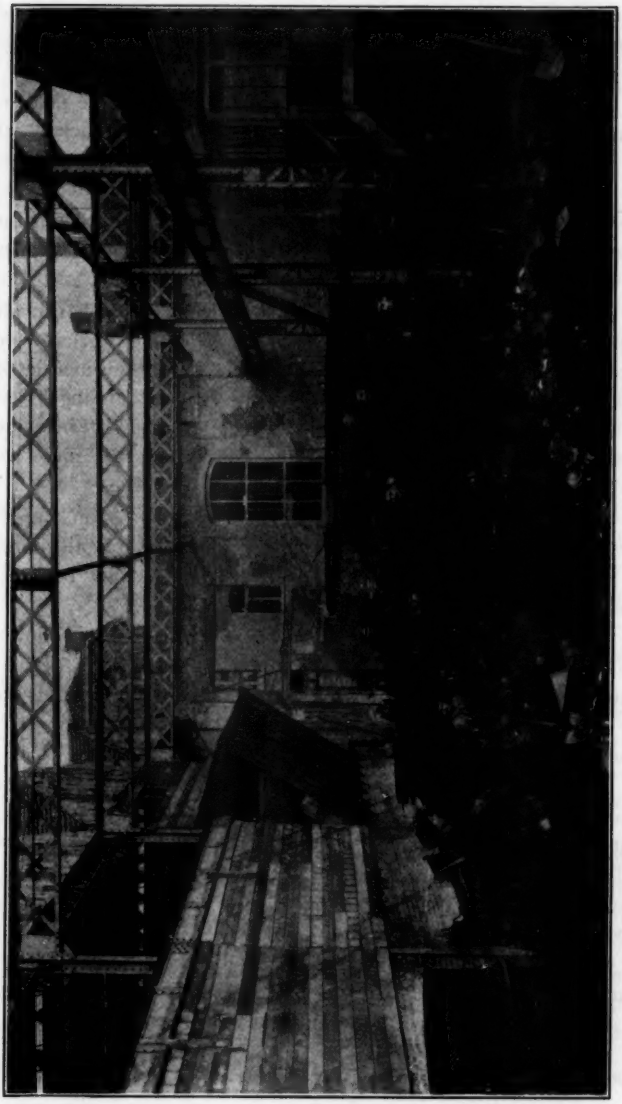

FIG. 20—THE COCARD FOUNDRY IN THE COURSE OF BEING CLEARED OF DEBRIS

specialize in the casting of machine bronze and titrated and phosphor bronzes. M. Jules Cocard is also a contractor for the railway companies and the navy.

The Cocard works, situated at 32 to 40 Rue de Valenciennes, Lille was of recent construction. The old factory at No. 13 was also destroyed. The various workshops composing it occupied an area of about 5,000 square meters.

The works consisted of a machine shop for the manufacture of cocks and valves, a pattern shop and a copper and bronze foundry. In 1914 the staff numbered 250.

After having suffered damage during the bombardment of the city of Lille by the Germans in 1914 the works were almost totally destroyed by the explosion of a munition depot on January 11, 1916. The value of the damage arising from the acts of war above-mentioned, from the seizures of machine tools by the Germans, and from the seizures of raw material, has been estimated at 1,700,000 francs (1914 value).

The work of clearance and rebuilding was begun immediately after the armistice. Owing to difficulties of all kinds this work, although carried on most actively, could not be completely finished until well into the year 1920.

As the general view given in photograph No. 16 shows, the works have been completely rebuilt. The various departments have been equipped with the necessary material and are now in full activity. The cost of reconstruction and the purchase of material amounted to about 5,500,000 francs.

Fig. 17 shows the entrance of the steel works and the destruction of the roof and cornices. The fitting shop shows what remains of the roof; several of the main rafters of the sheds can still be seen in position. The pattern gallery suffered seriously. Some patterns and core boxes can still be seen exposed to the weather admitted by the badly damaged roof.

Fig. 18, which gives a partial view of the foundry, shows great quantities of debris. Fig. 19 shows the destruction caused, and Fig. 20 shows the foundry in course of being cleared.

Making Typewriter Frames in a Belgian Foundry

By Joseph Leonard, Herstal, Belgium

(*Translated from the French*)

To secure a good practical result in the quantity production of typewriter-frame castings various conditions dependent upon the form of the whole piece must be taken into consideration. These conditions are governed by the size and relative position of the various bosses and sockets, by the necessity of producing a casting which may be machined readily, and by the necessity of keeping the production cost as low as possible.

The purpose of this paper is to present a few notes describing the method of molding and casting typewriter frames in a prominent Belgian foundry. Although the number of castings made is relatively large, the orders are probably not of a size which in the United States would be considered as placing the work on a quantity production basis. The maximum output provided for is 35 to 40 frames per day. This was considered insufficient for the installation of highly specialized equipment such as is found in American plants. Instead a comparatively simple rigging was designed to carry out the work.

The molds are made in a two-part aluminum flask, the drag being sufficiently deep to take the whole casting, the cope being nothing more than a flat cover. The casting is poured base upward, that is, the top of the typewriter frame on which the carriage runs is at the bottom of the mold.

The inside surfaces of the frame are formed by a large body core which has the same general shape as the casting and practically fills the mold. This core, which determines the metal section of only about 3-millimeters, or about ⅛-inch, must be very accurately centered. To accomplish this two machined iron guide-pin sockets, d_1 and d_2, Fig. 2 are cast in the flask. Pins as shown in Fig. 3 are fitted into these sock-

Presented through the courtesy of the Association Technique de Fonderie de Liege, of which the author, Joseph Leonard, is president.

ets or bushings. These pins engage similar bushings set in the core which is thus accurately centered without relying on the judgment of the workman. The mold is dried. Two sands are used in making the core as will be explained subsequently.

Turning now to the details, the writer will endeavor to describe as fully as possible the methods adopted for molding, coring, assembling and casting, and as these different processes are described, some of the difficulties encountered will be discussed and the means employed to remedy them set forth.

The pattern is in a single piece, and is of metal for the pur-

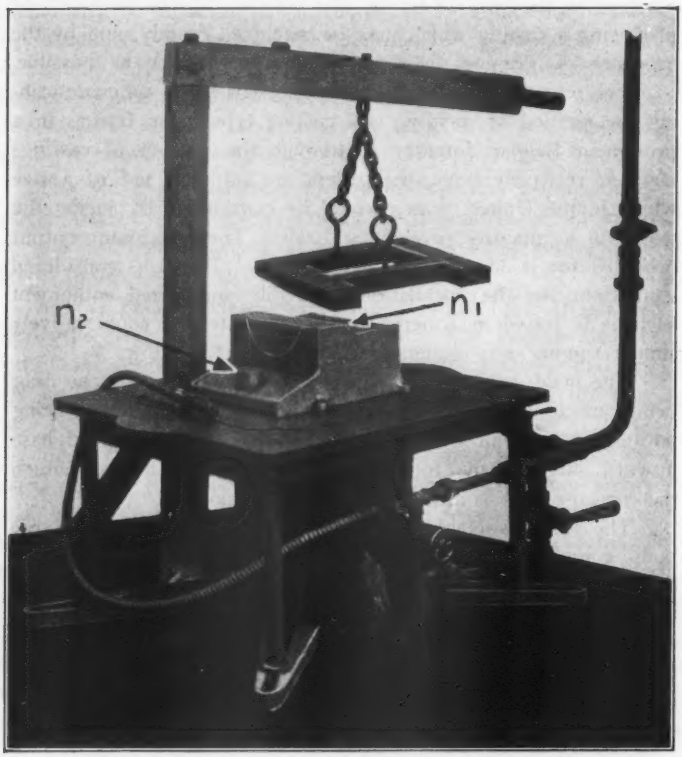

FIG. 1—THE MOLDS ARE MADE ON A JAR RAMMING MACHINE

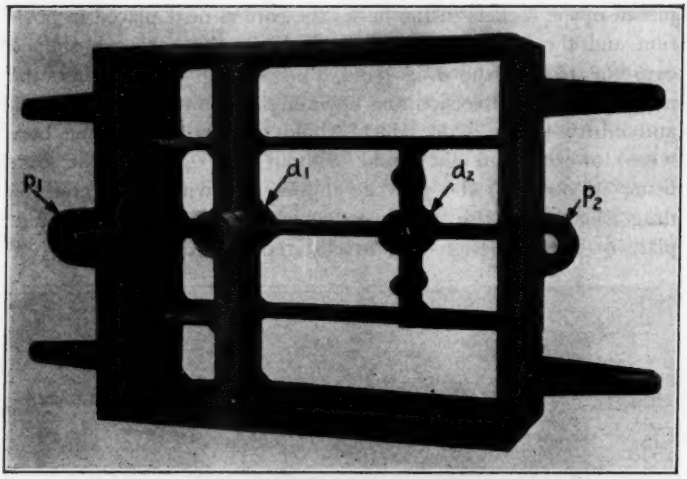

FIG. 2—THE DRAG FLASK

pose of ensuring strength and precision. It is molded on plain jar-ramming machines of a type manufactured in England. The flasks used are of aluminum, and the details of the pin and socket arrangement mentioned above are as follows: There are two ears, p_1 and p_2, Fig. 2 on the flask, and two internal sockets d_1 and d_2, joined to the flask by ribs. This combination serves to strengthen the flask, and the sockets d_1 and d_2 are milled on the ends and rest accurately on the upper portion of the pattern n_1 and on the boss n_2, Fig. 1. It is clear that these two surfaces are always equally distant from the part of the flask forming the joint, which is planed smooth.

The bore of the two sockets in the flask is 22 millimeters in diameter, and they are well centered in relation to the ears p_1 and p_2.

In the core box there are two pins f_1 and f_2, Fig. 7, their position corresponding precisely with the sockets d_1 and d_2 in the flask. While the core is being made two iron bushings b_1 and b_2, Fig. 5, are fitted over these pins.

On assembling the mold, two pins, e_1 and e_2, Fig. 3 are

placed in the sockets in the flask; the core is next placed in position and the iron bushings b_1 and b_2 in the core are slipped over the pins in the drag mold, thus setting the core into the mold with great precision and obviating the shifting of the cores and injury to the sand which would be inevitable if the core were lowered into the mold without any guide. The core being in position, the pins e_1 and e_2 are withdrawn and the drag is covered with a cope in which the runners fixed on a plate of special design are directly reproduced by molding.

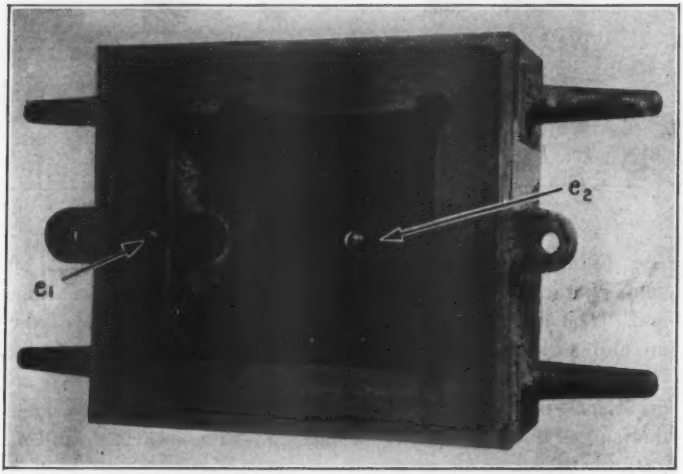

FIG. 3—THE DRAG MOLD SHOWING PINS FOR CENTERING CORE

As already mentioned the molding is done with a metal pattern, with stripping plate on a jar machine.

In adjusting the molding a rather serious and very obvious defect was encountered. Our acquaintance with jar machines is quite recent. We had thought that jar ramming was sufficiently uniform to enable the machine to produce a mold practically perfect. The result, however, was not as had been anticipated, and the upper portion of the mold was not really rammed; on casting, the whole of the corresponding portion of the mold was

swollen, the excrescences having to be removed in the cleaning shop.

We were led to make use of a cast iron plate which, during the jars, rammed the sand very firmly round the piece, and this practically eliminated the defect in question. I do not know whether there is any other remedy, but if not I consider that this defect, which must recur and which has been repeated in our work with all pieces having sharp angles, indicates a weak point in jar molding. This may be easily corrected for

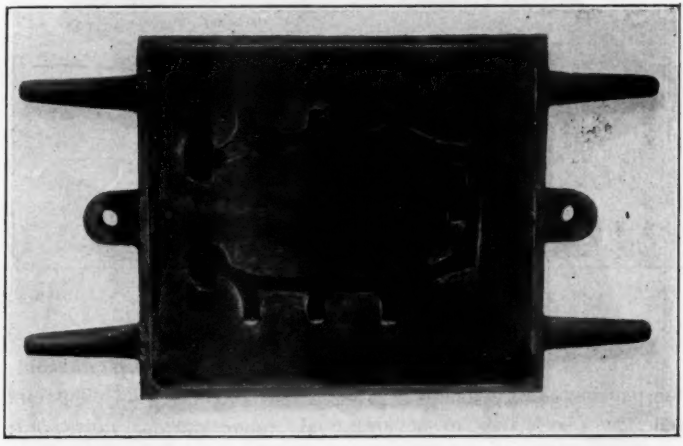

FIG. 4—COPE MOLD SHOWING GATES

pieces in series by using a plate, but it cannot be easily remedied for pieces not in series for which, it would seem, the jar machine is expected to be especially appreciated in Europe. This ramming defect has been observed not only by ourselves; among others, a large English foundry has experienced the same difficulty, and the jar machine operates as such for the first ramming. The sand in the upper part of the flask is rammed by hand. I mention this circumstance to our American friends who use jar machines regularly, and trust that I am not indiscreet in hoping to have their opinion on the subject.

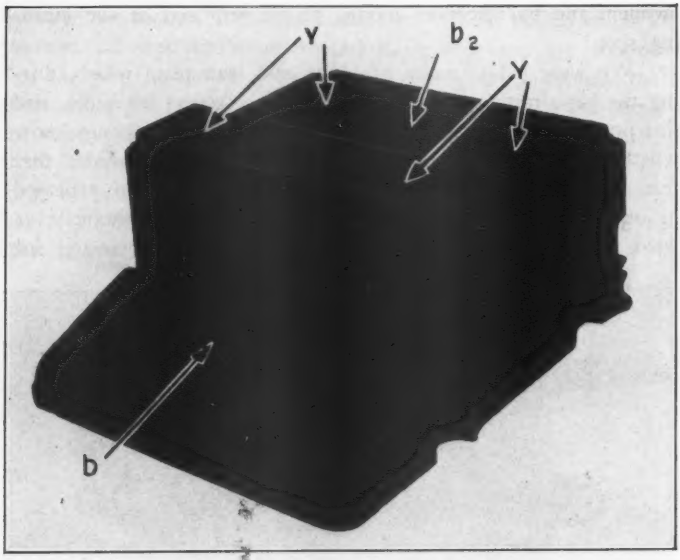

FIG. 5—MAIN CORE SHOWING BUSHINGS WHICH FIT PINS SHOWN IN FIG. 3

Discussion between the advocates of the jar machine and the plate molding machine is frequent in Europe. I would point out that, according to several trials made on flasks without cross-bars, the ramming of the frame dealt with in this paper is affected perfectly on a plate ramming machine. The fact that there are sockets and ribs in the flask is a difficulty in the use of these machines, but it may probably be obviated. I continue nevertheless to employ the jar ramming method, as the machine is installed and equipped with accessories and the results are good in practice; but if the manufacture of such castings had to be repeated I should consider the advisability of equipping a pressure machine for making the mold, and this with nine chances in ten of a successful result.

Molding Sand

The molding sand must obviously be prepared with very

special care in order to obtain a very fine sand and consequently a sufficiently smooth molding surface. The apparatus for sand preparation is simple, comprising a crushing mill and a separator. The sand on coming from the separator is further passed through riddles with a 5-millimeter mesh to complete the action of the separator. The preparation is done by the dry process.

Coring

The core box is of special construction. The shape of the

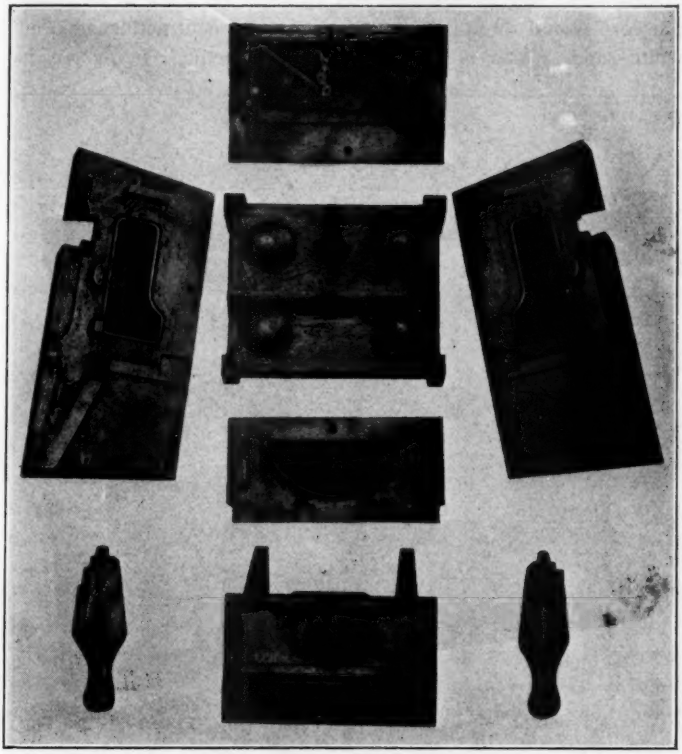

FIG. 6—CORE BOX PARTS

core itself has necessitated the form shown in the accompanying illustrations. The various plates, made of aluminum on account of strength and lightness, being released laterally for the withdrawal of the core, and being assembled inside the wooden frame for making the core itself, the exterior of the core is composed of siliceous sand with a binding of linseed oil, dextrine and "avebene." This layer is about one centimeter in thickness, the interior being filled with ordinary molding sand for reasons of economy and in order to withstand contraction in the casting. If the entire core were of white sand, the casting being thin and the portion of burnt sand not at all thick, the core would offer the same resistance to contraction as fired white sand, which is very great. This method, moreover, is

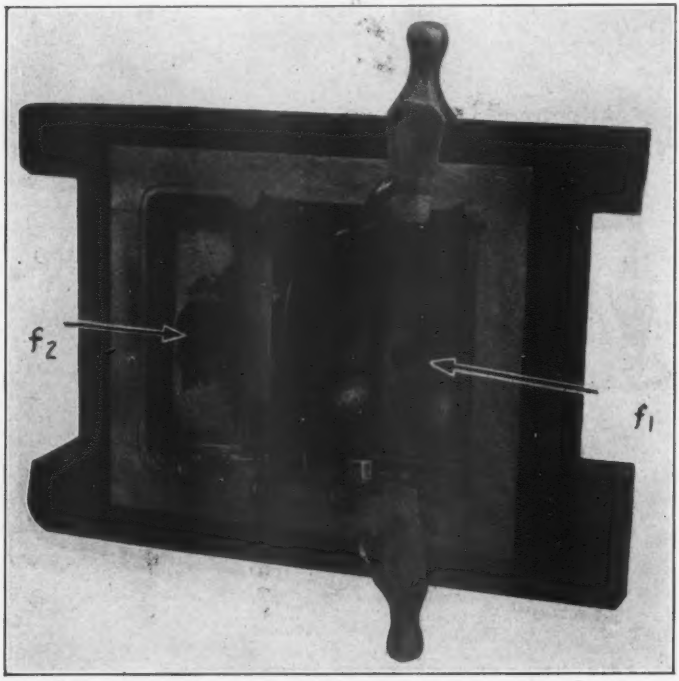

FIG. 7—CORE BOX ASSEMBLED

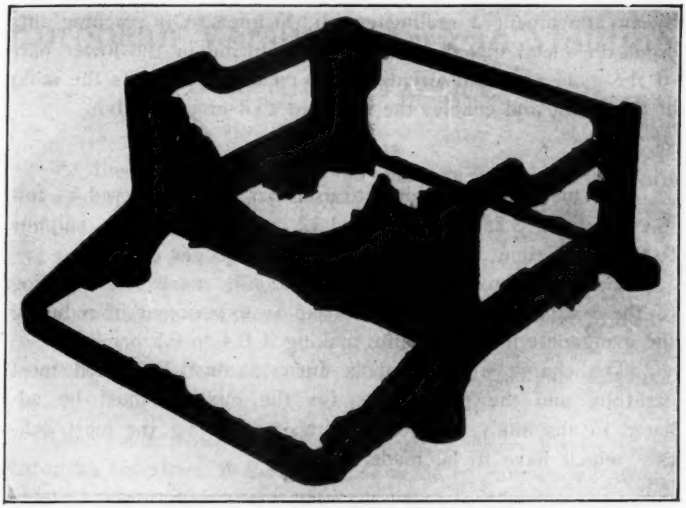

FIG. 8—ROUGH TYPEWRITER FRAME CASTING

perfectly useless, as the cores obtained are sufficiently strong to enable them to be manipulated. These cores are not blackened. The core makers are required to ram the white sand sufficiently to obtain a very smooth core surface and a sufficiently fine internal finish.

Pouring

Not only must the pouring of the piece be done very quickly but the metal must not have too long a distance to travel in entering the mold as it would cool too quickly, the mold would not be finished and the metal might harden. We use two basins for pouring and the molten metal enters the mold by a dozen tubes 7 millimeters in diameter placed all around the mold.

The mold is top poured; the metal, on reaching the bottom of the mold, cools too quickly and whitens. This is inconvenient in working the casting by machine or file. We obviated this by pouring into the lower part of the core large masses of metal shown at *Y* Fig. 5 connected with the casting

by an attachment 2 millimeters in thickness. On reaching this point the metal fills these cavities, producing in the lower part of the mold a certain circulation of metal which heats the mold at this point and enables the metal to cool more slowly.

Metal Used

The metal we have hitherto used has been composed as follows: Silicon 3.25, manganese 1.12, phosphorus 0.14, sulphur 0.09, total carbon 3.55, graphitic carbon 3.06 per cent.

In order, however, to facilitate still more the working of the casting we are about to make an experiment in reducing the manganese to a minimum, making it 0.4 to 0.5 per cent.

The charge of the cupola furnace must be tested most carefully and the proportions for the mixture must be adhered to absolutely, as these castings are among the most delicate which have to be made.

European Versus American Molding Machine Practice

E. RONCERAY, Paris, France

At the Columbus meeting of the American Foundrymen's Association H. Cole Estep gave a short description of molding machine construction in Europe. The object of this paper is to give an opinion from a European on the same subject, but adding thereto a description of innovations made from that time. American foundrymen will thereby learn the European point of view.

Comparison of Hydraulic and Compressed Air for Machine Operation

One point which strikes an American observer who visits European foundries, is the small use made of compressed air as a motive power, and on the other hand the considerable extension of hydraulic pressure, a factor practically unkown in American foundries. The reasons for this are simple and of prime importance. Compressed air at a pressure at from 60 to 100 pounds does not allow of the obtaining of high pressures on the molds and from this fact one can only use it for the making of small molds. For such work it is both rapid and practical but it is not good from the point of view of pattern drawing. In short it is incapable of giving steady and controllable movements. Thus allowance is made by means of some intermediate element to obtain the withdrawal of the pattern on precision lines by the use of an oil brake, specially designed hand starting mechanism or by similar equipment.

The leakages of compressed air into the atmosphere are not troublesome, but for this reason, they are neglected with the result that the power lost through them is often equal to or more important than the power actually utilized. A Wardle* says, "It is important to stop the smallest leakage in the pipe

*Paper delivered before the Birmingham Branch of the I. B. F., April 2nd, 1921. Foundry Trade Journal. June 2nd, 1921. p. 499.

system. A ¼-inch diameter round hole would allow air at 100 pounds pressure to escape at the rate of 100 cubic feet per minute, and 20 horsepower would be required to enable the compressor to cope with this leakage." However, by its nature compressed air is not economical, as the average motive power absorbed by each compressed air machine is from one to several horsepower and the section of the pipes is from one to several inches.

Water pressure on the other hand utilizes pressures varying from 750 to 1500 pounds per square inch. At these pressures, from eight to twenty times greater than those of air, the piston sections remain rather small, even for the higher pressures, consequently even for large molds, sizes of machines and prices can be kept within reasonable limitations. Water at high pressure at the same time makes for a low consumption and a high speed of water in the pipes, which therefore can be made of a small section.

In a carefully designed machine the water consumption is very low and the motive power absorbed is ridiculously small. Thus it is quite usual practice to work 20 molding machines at full output with a 5-horsepower pump, the main pipe being copper piping ⅞ inch inside and 3/32 inch in thickness. The water lends itself at the same time to rapid movements for the ramming and to the initial slow movements and then more rapid and steady movements for the pattern drawing. It is quite unnecessary that there should be any complication, and the most diverse movements can be obtained by small dimensioned parts.

Water leakages are troublesome, and obviously they require immediate attention which does away with both water and motive power losses. However, they may be avoided by the use of well made piping and leather or india rubber joints for the fixed parts, and high class packings for the moveable parts. The most important inconvenience is the freezing in cold weather, but it must be considered with no more importance than it deserves. First of all, a water return pipe and a non-freezing mixture can be used. All the types of water piping in towns and factories show that this inconvenience is more a

talking point than anything else. As a matter of fact, the temperature ought never to reach freezing point in foundries, because it is quite obvious the sand would freeze, and all work would automatically stop. As far as that goes, it is quite possible to empty the pipes or to use a non-freezing mixture. On the other hand, new machines described in this paper are so laid out that all the hydraulic sections are underground, which practically precludes any chance of freezing, the pipes being naturally underground also. Compressed air too, is not entirely free from frost troubles, for in the air pipe important condensations take place and the cooling due to air expansion may transform them into ice.

Is Jar Ramming Ideal?

Throughout the technical press, and in a few recent books, there will be found constantly repeated a false aphorism that is repeated as many printed things are, that jarring machines "are ideal as far as ramming is concerned."

We cannot possibly subscribe to this statement and we differ with the opinion expressed by many American foundrymen with whom we have chatted, that when pressure ramming is possible, it gives in the large majority of cases results superior to the jarring machines. We admit, however, that in a few limited cases the jarring machine can show advantage. It is an established fact and one which is easy of proof that an ordinary mold is better and more quickly rammed by pressure than by jarring.*

This we will show later on, but the fact that the number of pressure machines used in America for small and medium size molds are in outstanding majority, is sufficient proof.

It would be interesting to learn therefore, why jarring machines are in favor for large molds in America. Basically it is solely due to the impossibility of ramming large molds adequately by pressure, on account of the low pressure of the fluid usually employed. The skill of American engineers has turned to use the dynamic effort produced by the impact of a mass

*W. L. Lewis, Lecture before Franklin Institute, May 18, 1911.

raised by compressed air and falling down on an anvil, in place of the static effort derived from simple air pressure.

Ideal Ramming

We are far from that ideal ramming claimed very thoughtlessly. But, this is not the end. It is interesting to ask what is ideal ramming. It would be probably difficult to come to a unanimous agreement upon this point, for the foundry still remains in a state so empirical that every individual is possessed of an opinion on this subject, with more or less reason. It is perhaps possible to accept a statement that it would be rational that the hardness of the mold is proportional to the pressure of

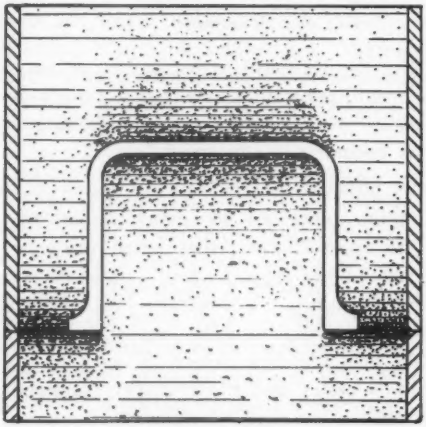

FIG. 1—SKETCH OF A MOLD RAMMED BY JARRING MACHINE

the metal, that is rammed softer from the bottom to the top of the mold, so that under such conditions the gas will escape through the sand in a regular manner under the variable pressure of the column of metal. Other people perhaps would like to have the part of the core surrounded by metal softer. Such opinions are sensible.

Taking as an example a split axle box, if we show darker the portions of the mold which are rammed the hardest, it will appear something like Fig. 1, a sketch for a mold rammed

by a jarring machine. For the drag it is exactly the opposite of what is required and if for the cope it is good for the joint it is bad for the higher portion of the casting. Unfortunately no means exist to do otherwise. On the other hand, pressure ramming permits the operator to vary at will the pressure on the mold (see Liege Congress discussion on molding machines). This is not all; it is a recognized fact that the shocks of jarring machines give much trouble in the foundry(*) and the number of highly ingenious contrivances which are supposed to overcome them merely show the number of troubles they cause. As a direct corollary, the bending of the flasks when working on flat molds renders the work extremely difficult, also the rebounding of the sand which occurs has lead to the adoption of numerous and highly ingenious arrangements. This rebounding renders the molding very difficult, especially for flat molds. Finally, jolt ramming produces, in sharp angles and under bosses, soft spots which were recently the subject of a highly interesting discussion at the congress of foundries technical associations at Liege.

Why Air Power Has Been Used in America

If, in spite of all these inconveniences jarring machines have assumed so great a development in America, it is because they have not only inconveniences, but they show also some advantages. These advantages are especially evident in very deep molds, the bending of the flasks being completely compressed. Under these conditions the rebounding is less dangerous. The differences of hardness from the lower to the upper portions of the mold are not so marked, and the packing of a huge mass of sand under these conditions is satisfactorily accomplished. Jar ramming does not necessitate the use of special ramming plates having the shape of the flasks as in pressure molding

*W. Lewis lecture before Franklin Institute, May 18, 1911. P. 24. "It is not generally safe to set up finished molds with hanging sand in the neighborhood of a jarring machine of this type and in some foundries the jarring machine has been out of service for days or weeks pending the completion of large floor work. In fact, the damaging effect of large jarring machine is too well known to need confirmation and to reduce this to a minimum, the drop of the table has been decreased while the foundation has been increased.

and in consequence no preparation whatsoever is needed for fitting the pattern for the machine. It is thus possible to use the jolt machine for short runs principally in order to ram, the pattern drawing being accomplished either on the machine or elsewhere. However it is a simple process, easy to understand by men used to hand molding who only see in the use of the machines a method of reducing their fatigue, all the remainder of the work being carried out similarly to hand molding. Briefly expressed, if compressed air pressure permitted the easy ramming of large molds, it is highly probable that the jarring machine would not have assumed such a great development, and we do not hesitate to say that in a country like England where compressed air is not very extensively used in foundries, and where hydraulic power is used as an everyday matter, it was a false step to have exploited the jarring machine rather than to have preserved it for special cases where it shows outstanding advantages. Jarring machines also permit the ramming of deep and narrow spaces in patterns such as those for long ribbed heating pipes, which, however, American molding machine makers declare impossible of attainment up to now.

Squeezer Machines

The use of squeezer machines has not always been understood. It is extremely easy to ram deep boxes with squeezer machines by carrying out the operation in several stages. Usually two squeezings are sufficient, and as this work of pressing is quite rapid and once made, the work is not partly but entirely finished without the necessity of butt ramming, striking off, etc. It will readily be seen that there are found in many cases distinct advantages from the use of the squeezer machine, even for the deepest molds, notably where pattern has projections, bosses, loose pieces and the like. European practice, particularly French, differs considerably in this respect from American practice.

While in America the aim has been to simplify machine molding by the employment of as many exterior and interior cores as necessary, in France the trend of affairs has been to keep the number of cores especially of a complicated nature to

the strictest minimum. By this method of working the cost price is reduced, for cores are expensive both in material and labor, and what is still more serious they give rise to complicated core setting and ugly fins which have to be fettled by hand at a price which is sometimes three or four times greater than the total value of the mold. Much cleaner work and a much lower cost price is obtained even though the production by the machine may be less, than if the molds made were merely to hold cores for forming the shape of the casting.

The objections usually associated with squeezer machines is usually due to ignorance as to the best means of carrying out the operations. It is quite common to find a foundryman new to the molding machine game who expects to produce machine molds by employing the same sand and by following the same method of working, etc.... as he does in hand molding. Without wishing to cast a slur upon foundrymen who go in for machine molding, it is not an exaggeration to say that any competence which they might possess in hand molding can scarcely help them if they are not desirous of getting the best results from the use of machines. Carefully studied, this fact appears more natural than paradoxial. Little by little machine molding methods have been involved and are distinctly removed from hand molding customs, so much so that the digression has become enormous and perplexes the most open minded persons. On the other hand, however, progress which has been made with regard to machine molding undoubtedly has thrown much light upon hand molding. The following example will illustrate this point:

Pressure Ramming Permits the Use of Drier Sand

On account of the incompetence of men operating machines, it is the custom not to permit them to patch the molds.

The pattern plate must be perfect and the pattern drawing accurate enough to give a perfect mold requiring no patching. Such a perfection in working conditions allows of the use of a much drier sand, the dampness essential for patching by hand being no longer necessary. Gradually the possibility of using dry sand has been recognized and has made possible the use of a dry sand which flows better under pressure, that is to

say, which approaches in this respect silica sand, which as everybody knows runs like water when it is perfectly dry. The ramming is thus accomplished under much better conditions than with a damp sand, but this is not everything. The dry sand which rams better, consequently no longer necessitates the use of a presser head close to the moderately restricted or deep parts but a simple finger touch before the squeezer ramming is sufficient. It does not scab and it remains so permeable that it is practically unnecessary to vent the molds. These new and highly interesting conditions have been brought about by the every day machine molding practice, and are too precious not to be profited by when molding by hand.

In the author's demonstration foundry which has been placed at the disposal of foundrymen, they are invited to take particular notice of the apprentices using for green sand molding practically the same sands as those used for machine work, and using little or no peen ramming, merely the hand tucking and the butt ramming and not venting. If sand breaks, it is damped only where broken and even then to the least extent.

This example is only one of the aspects of the question. Many others present the same divergence between old-time methods, and those resulting from a systematic study of mechanical molding.

This long discussion on the best motive fluid and the two more important methods of ramming has appeared to us as being of outstanding utility, as most ideas are in general confused on this subject, no matter how clear they apparently seem. It is given here without partisanship by a designer of the different types of machines discussed, who has them in regular service in his foundry, and above all with the idea of avoiding confusion to those who are under the obligation of making a choice.

Methods of Ramming Preferred in France

Thus the question resolves itself into the following:

A.—For all molds small or medium in boxes or boxless, relatively shallow, squeezing is to be selected.

B.—For all molds small or large, low or deep, where the pattern drawing is most important and for those where projections and numerous loose pieces are used the pressure ramming is to be selected even when it involves ramming by two or more squeezings.

C.—For large flat molds jar ramming presents great difficulties. Jarring machines are however, to be recommended where there is a special difficulty of ramming for which it is specially convenient (large number of narrow pockets of sand) in spite of the difficulties mentioned above.

D.—For large molds, of deep and simple castings in which the pattern drawing does not necessitate any great degree of precision, or when there are few molds to make, jar ramming is to be recommended. The finishing is then mostly made by hand.

E.—Water pressure is desirable in all cases for pressure machines, it alone permits of pressure ramming large molds.

This means that where hydraulic pressure is used, the pressure machine exhibits distinct superiority. The combination of the two methods of ramming can give good results, and it is at all times desirable that the pressure maintains the chief feature, which is rarely the case in existing machines.

Comparison of European Molding Machine Development

Germany

A foundry exhibition was held at Munich from Sept. 14 to 21, in 1921, but unfortunately only a few machines were working. The outstanding feature of this exhibition was the complete absence of originality in any of the types on show. On the other hand there were to be found more or less cheap imitations of American machines, as regarded jarring machines, and of French machines, as regarded the pressure type. Additional to this there were shown some simple pattern drawing machines the main feature of which mainly consisted in the pattern plate, and some pressure machines actuated mechanically or electrically, of which the principle, to our mind is bad, because of the fact that the purely mechanical working is scarcely

adaptable to the inevitable contact with sand, and on account of the multiplicity of the variability in the stroke and speed of the movements necessary to molding machines, and not showing any advantages over the use of a fluid as intermediary.

The Germans are always excellent in the construction of special types for pattern drawing on account of their proverbial patience, and abundance of skilled workmen which has always allowed them to undertake with success work of this kind.

Exhibit Electric Machines

Electric and other types of jarring machines were most numerous. Some were actuated by a simple cam in a similar manner to an American machine, while others inserted springs between movement and table.

General criticisms can be given of the German jar ramming machines which are actuated by a motor. The strength of the blow cannot be regulated, which is a distinct fault. This force should be able to be varied according to the weight of the casting to be made, the depth of the boxes and the type of work.* Finally tables on springs cannot be leveled accurately; consequently pattern drawing is more or less inaccurate.

Before leaving these German machines, and though the correction has been made in Vol. XXIX of the *Transactions* of the American Foundrymen's Association, we desire to correct the impression set out in the advanced copy of a machine described as of German origin. This machine is the first made by Bonvillain & Ronceray of the double faced type. The photograph reproduced had been taken in the manufacturer's works and no machine of this type, nor of a similar type, is made in Germany. The improved type of this machine is shown in Fig. 2.

Machines Made in England

Machines manufactured in England have been fairly completely described in the paper by H. Cole Estep. It only

*W. Lewis page 29 "good practice sometimes requires a short stroke followed by longer ones as the sand settles in the flask."

seems necessary to add that some of the types which were not mentioned are fairly well known.

French Machines

As mentioned by Mr. Estep, there are in France only a

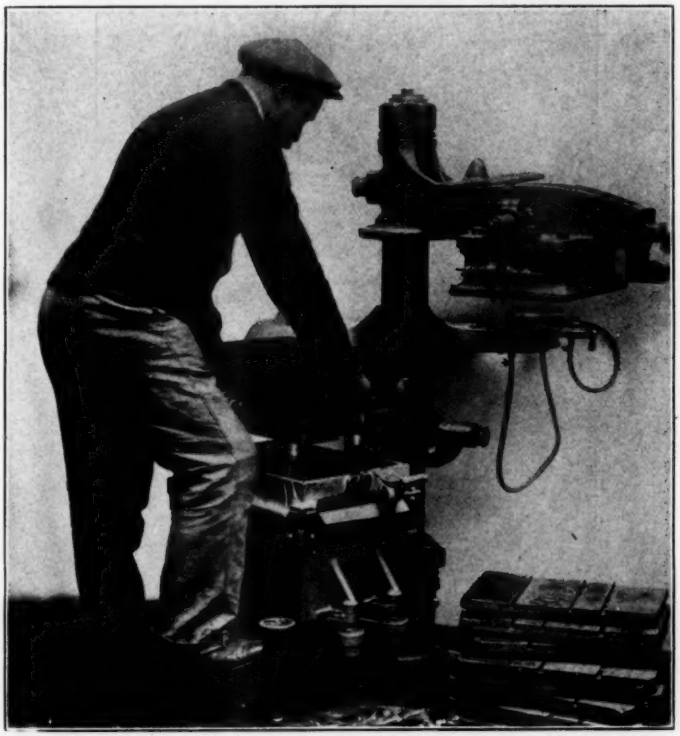

FIG. 2—IMPROVED TYPE OF MACHINE MADE BY FRENCH FIRM

restricted number of manufacturers of moulding machines. There are, however, nearly a dozen, but if the number of designers is restricted, the number of machines constructed is relatively important, and the machines manufactured are noted throughout the entire world.

Some half-dozen manufacturers are specialists in hand-operated machines, and turn out excellent types, which are really quite different from those constructed in either America or England.

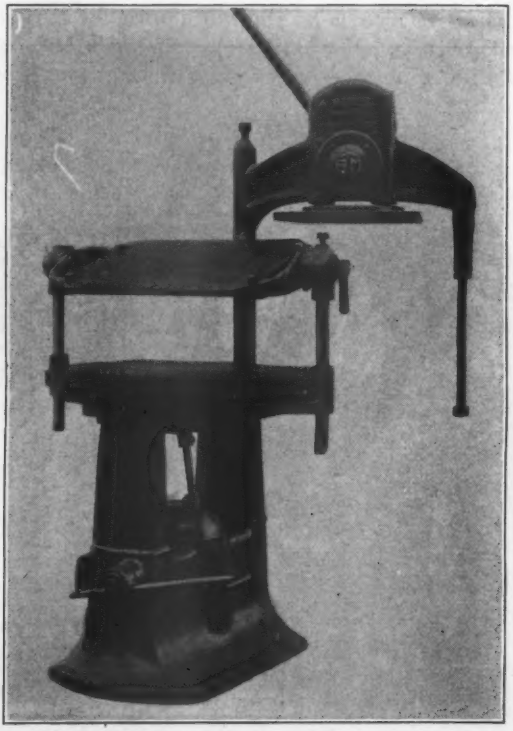

FIG. 3—SMALL HAND MACHINE MANUFACTURED IN FRANCE

We give below some illustrations of the different machines with the names of their designers:

Fig. 3 represents a small hand machine made by A. Marillier. The column and hook are adjustable so that available height between table and presser head can be altered.

The firms of Baillot and Utard make hand machines sim-

ilar to this, but we could not obtain photographs of them. The Utard machine for large moulds is worked by two levers.

Fig. 4 refers to Bonvillain & Ronceray hand moulding machines. Ramming is obtained through a long lever working a pinion and a rack. It can be adjusted by setting the three bolts shown in front in a circular groove cut at the end of

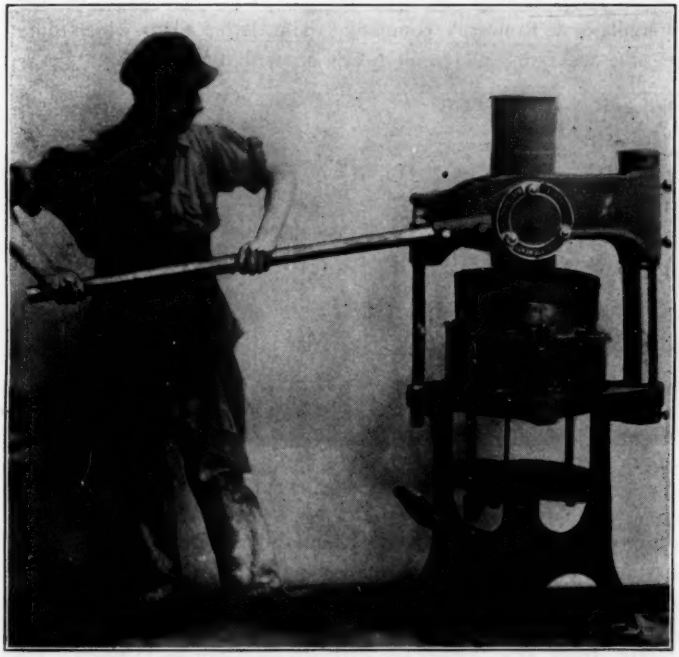

FIG. 4—ANOTHER FRENCH MOLDING MACHINE, OPERATED BY A LONG LEVER ACTUATING A PINION AND RACK

the pinion shaft. Pattern drawing is made through a pedal shown on the side of the machine.

One firm, Glaenzer & Perreaud, manufactures Nicols pneumatic machines. Another makes on a small scale jarring machines, with a cam based on the American principle. They are designed by an engineer who has passed a portion of his

life in America. A third, Gailly, manufactures a hydraulic machine, in which the two parts of the box are rammed side by side for the production of flat castings.

The Diederichs concern makes types of hydraulic machines with turn-over tables, which have been manufactured for a long time by German firms and the French concern of Desmarais and Morane incorporated some 10 years ago by the Bonvillain & Ronceray company. This latter firm, which during the war was, above all taken up with the intensive supply

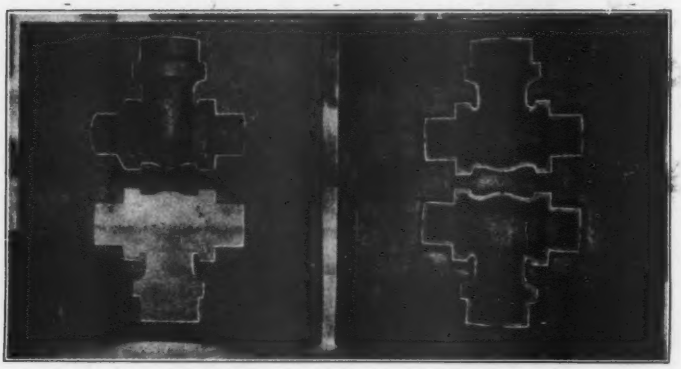

FIG. 5—A PATTERN PLATE AND STRIPPING PLATE MADE IN A SINGLE CASTING AND SEPARATED BY CHIPPING

of material necessary for the manufacture of cast-iron shells, has now returned to its normal manufactures and it may perhaps be interesting to pass in review the most recent types of its different machines of which the general construction is different from any American, British or German designs. Because of the scarcity of mass production in France, it has been necessary above everything else to create methods of making pattern-plates, allowing of the making of these pattern plates at a low price, and relying largely upon moulders' work.

Fig. 5 shows a pattern-plate, made up of metallic shell, and its stripping plate, both of which are made in one single casting. This obviously ensures an absolute registering between the pattern and the stripping plate. The stripping plate

and the pattern-plate are detached by means of a very fine chisel, which allows a tiny play around the pattern. This represents an extremely simple case. The work would be the same, if instead of a double pattern plate, that is to say one allowing for the separate molding of the upper and lower boxes, it was necessary to make a reversible pattern-plate.

The most complicated castings can be made by similar

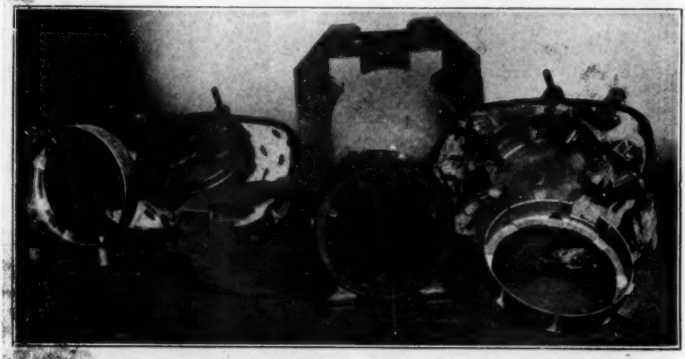

FIG. 6—PATTERN PLATE FOR A DYNAMO FRAME

processes, an example being illustrated in Fig. 6, which represents a dynamo frame, made on the machine leaving its central core in the mold. It is one of the extremely rare cases where the peg rammer should be used to ram in the interior parts of the core. Special note should be taken of the fact that in this pattern plate, there are a considerable number of loose pieces, which permit the making of a very complicated casting being produced without hand-made cores, and without fins on the castings. The machine which is shown in Fig. 7 is the one which has carried out this work.

Machine Accommodates Intricate Work

The illustration shows the machine working on the pattern of an automobile change-speed gear box. The complication of this work is difficult to show on a photograph, but it is very interesting to note the manufacture of a part which used

to be separately cored, but which is here made in a one single piece, with seven loose pieces in the drag. Moreover in

FIG. 7—MACHINE WORKING ON BOTH SIDES OF AUTOMOBILE GEAR BOX

the ears marked "T" are cores, and this highly interesting work represented is explained in detail in *The Foundry* of Feb. 15, 1922. The opposite half which is very deep was rammed in two operations on the machine without use being made of hand

ramming. The first half was made in 3 minutes 41 seconds, and the second size in 8 minutes 18 seconds.

With reference to turn-over machines, Bonvillain & Ronceray have also made some important progress, as shown by Fig. 8. This machine is similar to the previous ones, with the

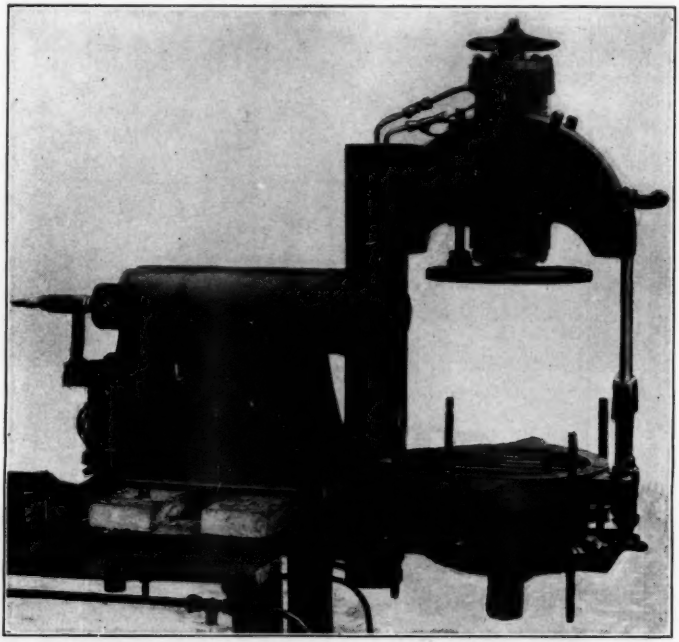

FIG. 8—AN EXAMPLE OF TURN-OVER MACHINES MADE BY A FRENCH MANUFACTURER. NO PIT IS REQUIRED IN FRONT FOR ROTATION

difference that it does not require a pit in front, in order to permit the rotation of the machine. The machine does not rise above ground level, and in consequence its use is rendered much more handy, but its capacity is slightly less, its ramming stroke and pattern-drawing arrangement is only 12 inches, instead of 16 inches, which correspond to the dimensions of fairly large moulds.

Instead of being provided with a swinging head, the table rotates round the column and is thus brought to the side of the machine, giving an arrangement, which is advantageous, when it can be used, so that the table is in position near to the sand-heap.

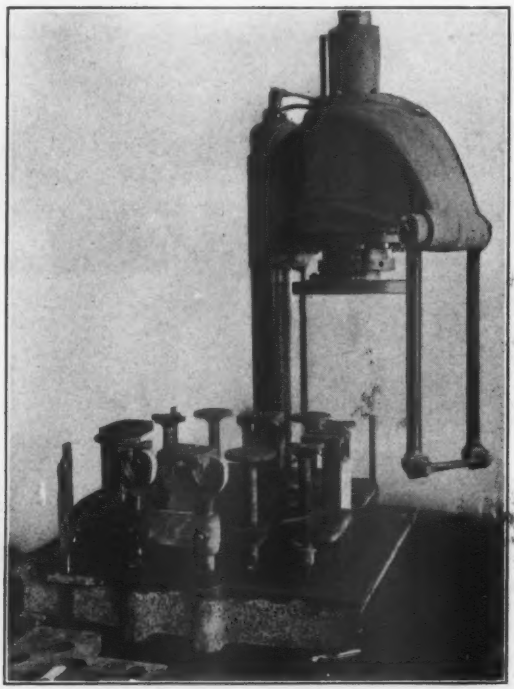

FIG. 9—ROLL-OVER MACHINE OF FRENCH DESIGN 48 INCHES BETWEEN COLUMN AND HOOK

On the other hand, it is not easy to have a pattern-drawing arrangement, with such a long stroke, as in the case of the other machine.

The rolling over of the machine is obtained by means of a cylinder, and one single piston worked by a lever, which is clearly shown at the side of the machine. A hand wheel

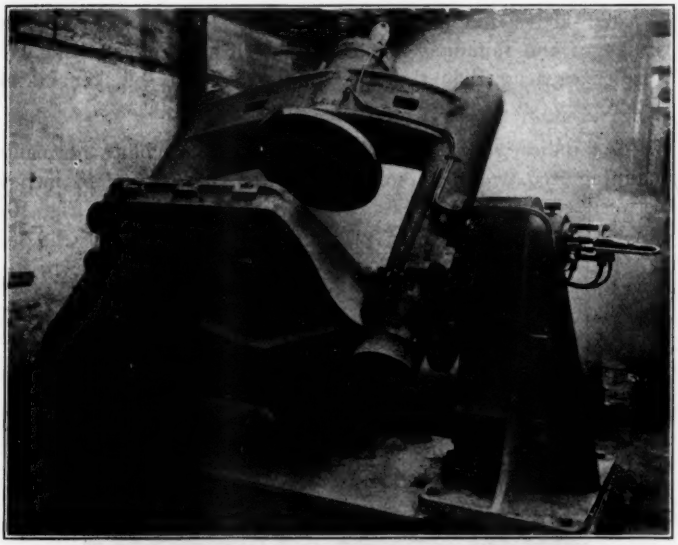

FIG. 10—ANOTHER SIMILAR MACHINE, 55 INCHES BETWEEN COLUMN AND HOOK

FIG. 11—EQUIPMENT FOR MOLDING LARGE MOWING MACHINE WHEELS IN FRANCE

situated above the pressure-head is used for regulating the stroke of the ramming plunger. This machine has a slightly smaller capacity than the preceding one but is quicker in its action.

As indicative of the sizes of the large machines normally manufactured, we show in Fig. 9 a machine having 48 inches between column and hook, and the rotating machine, Fig. 10,

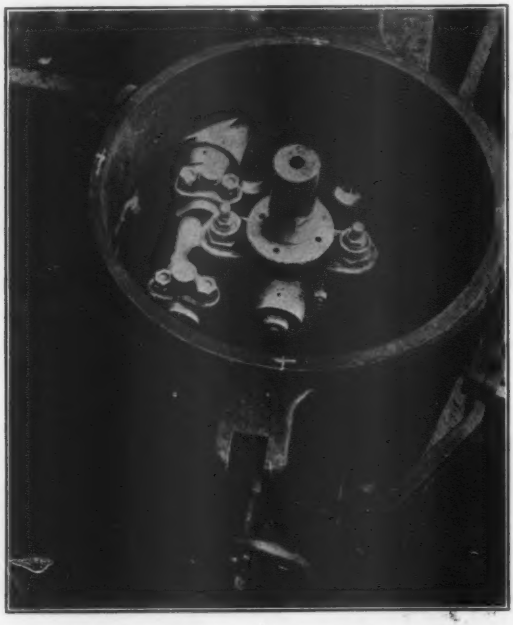

FIG. 12—SMALL JAR-RAMMING MOLDING MACHINE OF FRENCH DESIGN

having 55 inches between column and hook. These machines are suitable for wagon wheels and similar large castings.

The most recent model of the type, shown at Philadelphia in 1907, does similar work, to the split patterns and stripping plates machines of the American designers, but are suitable for

variable sized boxes, which is not the case of the American machines.

The outstanding feature is the total elimination of joints, connections and piping in the machine. All hydraulic arrangement is under the table, and in consequence there is no neces-

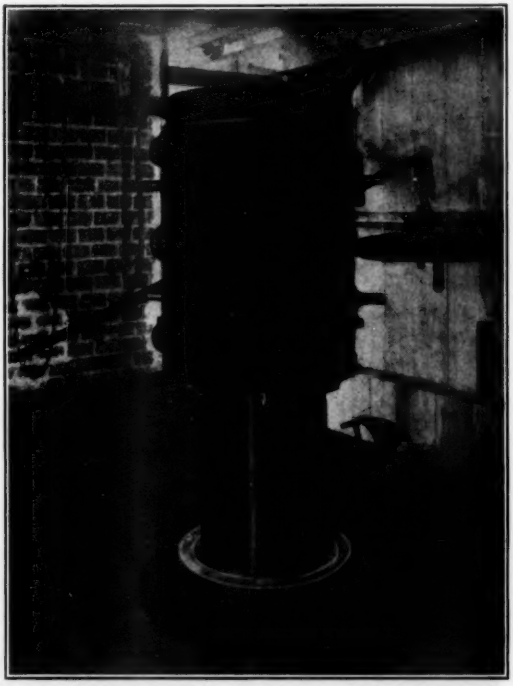

FIG. 13—A FRENCH MACHINE FITTED UP FOR MAKING SHELLS

sity to have apparatus to bring the water to the head of the machine. Moreover, the water is brought to the lower cylinders by means of holes drilled through the cast-iron, so that keeping up is very simple and the dangers of frost completely eliminated. Their simplicity and ease of service are remarkable.

One lever only works all the movements. By pushing to the right, ramming is effected, whilst a motion to the left withdraws the pattern. In the middle position the two movements are neutralized. The pattern drawing can also be effected by a pedal fixed to the lever.

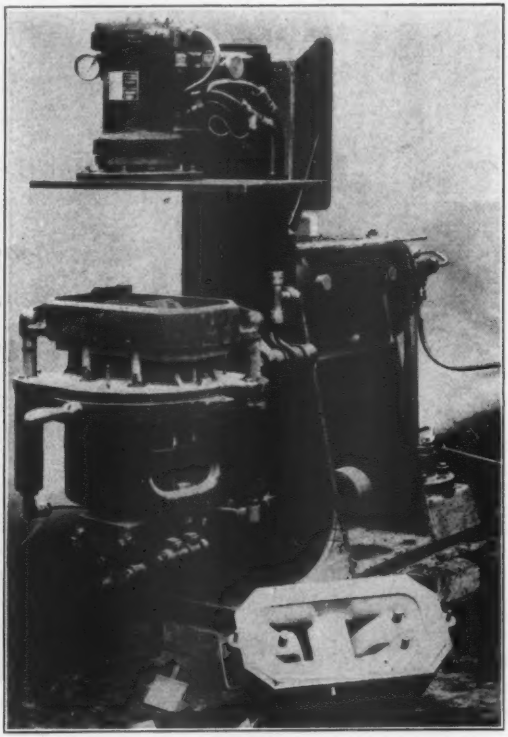

FIG. 14—A MACHINE ON WHICH RAMMING AND PATTERN-DRAWING ARE PERFORMED WITH A SINGLE RAMMING STROKE

This firm manufactures interesting jar-ramming machines, based on a principle entirely different from those made up to now. They are machines which are provided with mechanical

hydraulic movements, the smallest of these machines is shown in Fig. 12.

Fig. 13 shows the same machine fitted up for the manufacture of shells.

In his communication to the Franklin Institute, W. Lewis

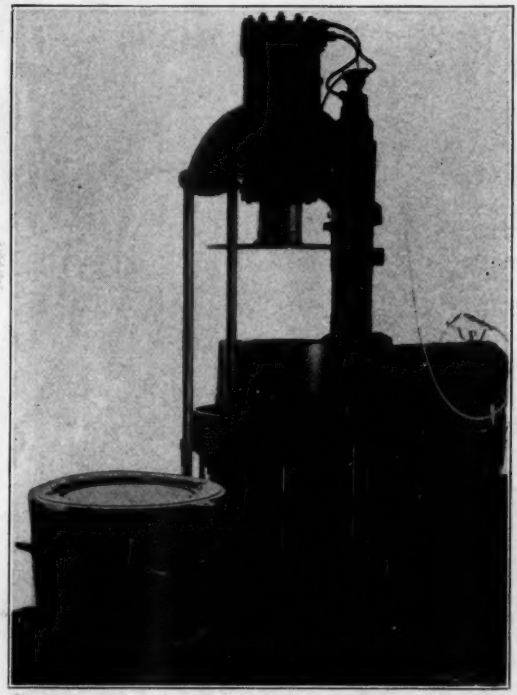

FIG. 15—SIMILAR WORK ON A MACHINE ON WHICH MOLD IS TURNED OVER FOR PATTERN DRAWING

states that in order to overcome the difficulties coming from the top of the box, and the pattern being not rammed equally, "bottom ramming machines in which the patterns were pushed up into the sand, were recognized as ideal in principle, and they were used with more or less success. But the method is

FIG. 16—MAKING CASTINGS EMBRACING COMBINED CYLINDER AND CRANKCASE OF OIL ENGINES IN AN ENGLISH FOUNDRY

opened to the objection that it necessitates a predetermined quantity of sand reduced in bulk by a definite amount of compression and these conditions upon which success depends are not always realized in practice."

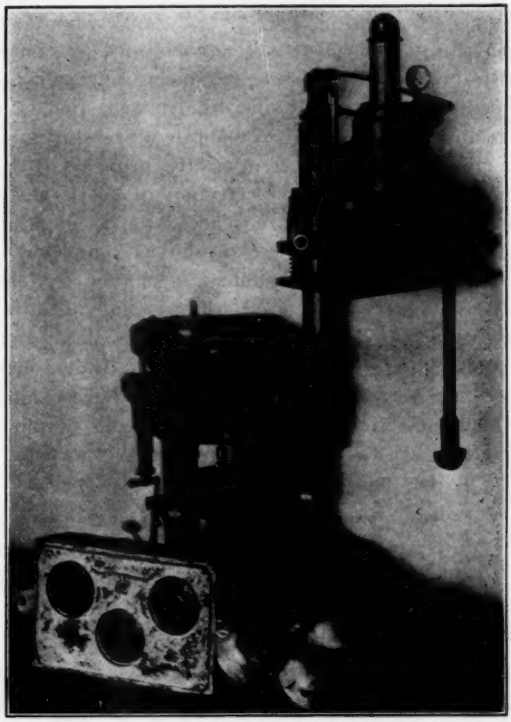

FIG. 17—A MACHINE FITTED UP FOR MAKING SAUCEPANS

In reality these difficulties are much less when sand as dry as possible is used in the machines.

Bottom ramming, which we call "down-sand frame," because, instead of raising the patterns, the box is suspended on a movable frame and is made to descend, is only recommended in a limited number of cases, for the pressure of dry sand is

transmitted sufficiently well to render useless such arrangements especially where the production is not extremely large.

But in the last case, and for special applications it is superior in point of speed and workmanship to any other system and especially to jar-ramming machines.

American foundrymen will probably be interested in a few illustrations showing some interesting applications of this arrangement, which has only one disadvantage, that is, it necessitates relatively costly and complicated accessories. On the other hand, once these accessories are provided, the production is considerable and the perfection of work ideal. Ramming and pattern-drawing are made with a single ramming stroke, the mold being in these conditions completely finished, even if there are a limited number of narrow sections in the mold because there can be used for ramming in such sections a bar of suitable shape in the box, and even to ram on the side of the pattern, sloping sides boxes. Under such conditions there can be made railway-chairs, which need lateral ramming at the same time as the inside ramming in the rail section. Fig. 14 shows such work, where the mold is entirely completed in less than one minute (three loose pieces).

Fig. 15 shows similar work for a very large casting needing rolling over for pattern drawing. The manufacture of a casting composed of oil engine cylinder and crank case combined, taken in the foundry of Messrs. Petters Ltd., Yeovil, England, is shown in Fig. 16.

Fig. 17 shows machines fitted up for making saucepans, of which the handles are drawn from the sand before pattern-drawing.

Machines with similar arrangements are used for the large rotating machines, making mower and wagon wheels, are shown in Fig. 11.

We hope that the above notes will show the advantages to be derived from the exchange of ideas between the different foundry technical associations.

The differences existing between the methods of the di-

verse countries will diminish by discussion and comparison by practical men.

We desire to express in closing, the regret that joint foundry exhibitions and conventions, because of distance and language difficulties, could not be held alternatively in the different countries where foundry technical institutions exist, in waiting the moment when real peace will allow the holding of such meetings in every industrial country.

But I can express the desire that in the coming years the English, Belgian and French Associations should hold a joint meeting in rotation in their countries with an exhibition with the idea to make such meeting and exhibition a very important event of their industrial life.

The author gratefully acknowledges the assistance given to him by V. C. Faulkner, editor of *The Foundry Trade Journal* in the translation of this article from French to English.

American Versus British Gray Cast Iron

By F. J. Cook, Birmingham, England

Rightly or wrongly, the average British engineer and foundryman considers that American gray cast irons of their respective class are inferior in physical properties to those of Great Britain. He bases this opinion, first of all, upon the undoubtedly poor wearing qualities of the cast iron which some years ago formed the material of the large quantities of machine tools sent to England. It was commonly said that the cast iron was so soft as to be easily cut with a pocket-knife, a statement often enough literally correct.

Recently, some improvement has been noticed, attributed partly to wider bearing surfaces and the application of chills on wearing parts, combined with the use of semisteel. Nevertheless experiences are still related, in connection with the war, showing that American material frequently left a good deal to be desired. The author was familiar with an American machine supplied by a well-known maker which was commandeered by the government for a special operation in connection with parts for large guns. Owing to the poor quality of the cast iron the machine was constantly breaking down. No fault could be found with the design which was excellent for its specific requirement; yet owing to the long periods when it was out of commission through breakdowns the output was less than that obtained from an improvised old machine. It was necessary to replace the broken parts with castings produced from local irons, utilizing the broken portions for patterns. These substituted parts proved quite satisfactory, and there was some foundation

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This paper is one of a series on foundry problems being exchanged between the Institution of British Foundrymen and the American Foundrymen's association. The first, prepared by George K. Elliott of the America Foundrymen's association, was presented at the 1921 meeting of the Institution of British Foundrymen. The author of the accompanying paper, F. J. Cook, is one of the outstanding figures in the British foundry industry. He is a past president of the Institution of British Foundrymen, and is manager of Rudge-Littley, Ltd., West Bromwich, near Birmingham.

for the statement, although not strictly and literally true, that the only part remaining of the original cast iron in the machine at the end of the war was the name plate on the bed.

Writers of scientific papers in America frequently refer to the failure of cast iron parts under superheated steam. This is a state of affairs very unusual in this country, gray iron castings being made here without difficulty sufficiently strong to withstand working temperatures and pressures quite equal to those under which American castings have broken down. The composition of this more durable material is not widely different from the American irons which have proved unsuitable.

Some years ago an American technical journal with which the author was familiar regularly gave reports of burst flywheels, until at last it became quite natural to look for them with very much the same amused interest as the readers of *Punch* anticipated the historical cartoon. English engineers regularly engaged in designing cast iron flywheels up to a weight of 56,000 pounds having periphery speeds of not less than 100 feet per second sometimes wondered as to the character of the remarkable material of which the American wheels were made.

Travel naturally widens one's views and extends one's knowledge, and, conversely, there is a tendency on the part of the stay-at-home to become parochial and narrow. One of the results of the war has been a more frequent interchange of visits and we on this side from a period shortly before the end of the war consider ourselves specially favored in the visits we have received from many leading American foundrymen, whose eminence consists not only in foundry knowledge but in general accomplishments. We hope they will pardon the amusement we have derived from the very candid opinions they have expressed in regard to us and our institution in the old days before, like the Queen of Sheba, they came to see for themselves. One American, for example, expressed the belief that British foundries were generally so badly lighted that an electric torch was necessary to find one's way about in them; moreover the molding shops were so low that one had to be careful not to knock his head against the roof principals. He

was candid enough to say that the first British molding shop he entered fairly took away his breath. After spending the whole afternoon in it he regretted his inability to stay longer and see more. He discovered that he had only seen a small part of the whole, and was a litlte surprised at the offer of his guide that "any time he had a week to spare they would be pleased to show him the remainder." As a matter of fact he was in the largest foundry in the world, and had no idea that so fine a concern could be found on this side of the Atlantic.

The author has to admit that up to the present he has been among the stay-at-homes and is quite prepared to find that his references to American practice will furnish foundrymen on the other side of the Atlantic with at least as much amusement as Britishers have derived from Americans and their opinions of Great Britain. The great purpose of the paper, however, is to furnish a basis for a good discussion and it may be hoped that this object will be realized.

As the subject of gray cast iron obviously is too wide to be dealt with in a single paper, it is proposed to limit its scope to the consideration of gray cast iron made from commercial pig irons, and cast iron scrap melted in a cupola by means of coke, and without the addition of steel or any ferrous or nonferrous

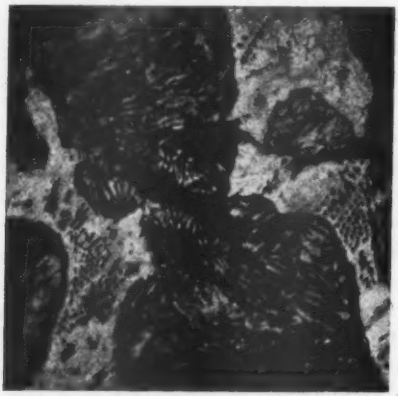


FIG. 1—GRAY CAST IRON HAVING A TENSILE STRENGTH OF 41,216 POUNDS PER SQUARE INCH X 1000

materials introduced either into the cupola or the ladle of molten metal.

When one comes to deal specifically with mechanical tests, the fact has to be faced that the conditions relating to mechanical tests for cast iron vary considerably in the two countries. Little importance appears to be attached in America to tensile testing, while the size of the transverse bars tested equally with the method of testing differs widely from British practice. The ruling tests for cast iron may be said to comprise in Great Britain: For pipes, constructional and general engineering work for more or less rough and large character, transverse bars, 2 inches deep 1 inch thick and tested deep part down on centers 3 feet apart; for engine details other than cylinders, transverse bars 1 inch square tested on centers 12 inches apart. It is also becoming more general in the finer classes of engine work to cast the transverse bars 1 1/4 inches square, machining down to 1 inch square to insure accuracy. For cylinders of all descriptions tensile bars are demanded, exactly of the same material as the castings they are to represent. Practically every tensile bar has to be tested in the presence of an inspector, and the casting of the bars on the job therefore, generally gives more satisfaction and prevents the suspicion which might possibly arise if the bar was separately cast without the presence of the inspector. There is a great deal also to be said in favor of the tensile test for cylinders, since the castings themselves are necessarily subjected to tension. Moreover a tensile test gives a better indication of the wearing properties of this class of iron than any other test known to the author.

It may possibly be that the apathy with which the tensile test in America is regarded may to some extent be due to certain conditions named by Dr. Moldenke, though of that, of course, the author is not in a position to judge. Dr. Moldenke says:*

"In this country (America) you will find about 99 out of 100 testing machines that are not in proper condition for the tensile test. On the other side they calibrate the machines often, and they have their governments to test them."

There can be no gainsaying his statement on the same

*A. F. A. Volume XXII, page 368.

page that "for scientific investigation the tensile bar is preferable."

The reading of American scientific papers and of the technical press conveys the impression that a tensile test going a little beyond 31,360 pounds is considered worthy of special notice; certainly in this country anything like this would be considered quite mediocre. Mr. Ernest Wheeler,* representing Messrs. Crossley Bros, Ltd., Manchester, states that he has found it "quite possible, without the aid of steel to prepare and obtain mixtures of cast iron having a tensile strength of over 18 tons (40,320 pounds) per square inch, and this is confirmed by other workers in the same field. The same gentleman has prepared for the author a bar cast in accordance with the

*Manchester Association of Engineers, *Proceedings*, 1921.

FIG. 2—GRAY IRON WITH TENSILE STRENGTH OF 44,486 POUNDS PER SQUARE INCH X 1000

Table I
Results of Tensile Tests

Total carbon	Analysis						Tensile test result, lbs. per sq. inch	Transverse test equivalent, lbs. per sq. inch on Arbitration Bar
	C. C.	G. C.	P.	Si.	S.	Mn.		
3.054	0.98	2.074	0.974	1.213	0.146	0.324	32704	5146
3.054	0.84	2.214	1.046	1.166	0.136	0.432	32720	5146
3.3	0.89	2.410	1.140	1.40	0.134	0.453	36064	5146
3.163	0.665	2.498	1.186	1.40	0.136	0.465	39200	5373
3.272	0.84	2.432	0.981	1.143	0.137	0.288	41440	5562
3.21	0.72	2.49	1.2	1.49	0.126	0.420	44486	5600

specification for the "Arbitration bar" which has given a result of 39,200 pounds.

A short time ago the author tabulated his average tensile test results over a working period of 500 consecutive days. The average figure was 36,288 pounds per square inch; no test was as low as 30,240 pounds, while the highest figure reached was 43,008 pounds. All the bars were 1 1/4 inches diameter and were cast on the castings they were to represent—not separate—and were turned down in the middle to 1/2-square inch area before testing. A typical range of tensile test results with this class of iron with the analyses is shown in Table I.

For mechanical tests to be strictly comparable it is essential that the bars should be of the same dimensions and similarly molded, gated, cast and tested. It may be argued therefore that the tensile test results given in Table I are not comparable to those obtained by the American arbitration bar. But the author suggests that in this respect the advantage has not been with those cited. The bars were of the same dimensions as the arbitration bar, and they certainly had the advantage of static pressure due to casting head, as they are placed on the middle joint of short stroke cylinders. They have one disadvantage, however, in that they were cast with cooler metal than if they had been cast from a small ladle direct from a cupola, while the rate of cooling is slower, owing to their having been cooled down in close proximity to a larger body of metal. The disadvantages of all these conditions were well set out in the admirable exchange paper presented by George K. Elliott to the Institution of British Foundrymen last September.

Comparisons between the transverse tests made in the two

countries are necessarily hampered by serious difficulties, chiefly on account of the difference in shape and dimensions of the bars used. The arbitration bar has a diameter of 1 1/4 inches and is tested *as cast,* on centers 12 inches apart. The bars with which the author is familiar and of which particulars are given later are cast 1 1/4 inches square, machined down to 1 inch square, tested on 12-inch centers, and cast on to castings, as previously defined in connection with the tensile test.

In the absence of an available machine suitable for taking a bar of 1 1/4 inches it has been necessary to evolve a constant which will reconcile the differences of dimensions in the two bars.

The results of the arbitration bar can be converted into those comparable for a 1-inch square bar tested on the same center by multiplying the breaking load obtained by 0.74; conversely the result obtained on the 1-inch square bar divided by 0.74 will give the equivalent load on the arbitration bar. The formula used for obtaining this factor is given in the appendix to this paper.

In the discussion on Mr. Elliott's paper already referred to, the author gave some details of 25 transverse tests of bars giving an equivalent average breaking load on an arbitration bar of 5300 pounds; the lowest bar gave an equivalent load of 5146 pounds and the highest 5600. The minimum load is a higher figure than that obtained by Mr. Elliott with American metal having a similar silicon content, but with lower phosphorus and sulphur after undergoing the refining action of an electric furnace.

Table I gives particulars of the transverse results brought up to an equivalent on the arbitration bar relative to bars cast on the same cylinders as those selected for tensile example.

Although the two previous tests are not in the strictest sense comparable, there is a mechanical test common to both countries, namely Keep's shrinkage and transverse test. The author was probably the first in Great Britain to have at his disposal a complete set of Keep's machines, and the present opportunity is gladly taken to acknowledge the great value

of the shrinkage and transverse test in connection with this class of cast iron.

A rather lengthy correspondence took place with Mr. Keep relative to the working of the transverse machine with the 1/2-inch shrinkage bars. Mr. Keep expressed the opinion that the alignment of the machine had become affected during its transit. He arrived at this conclusion from the high results shown on the diagrams forwarded to him. In regard to these he said, "Probably we should not have a 1/2-inch square bar to break at over 425 pounds." Nothing could be found wrong with the machine and as the results appeared to be borne out by other mechanical tests taken on bars of varying sizes from the same metal a few 1/2-inch bars were sent to Mr. Keep with a diagram of the corresponding bar in each set. The breaking

Table II

KEEP'S TESTS

Shrinkage inches	Transverse Breaking Load in pounds	Deflection inches
.146	550	.14
.161	600	.15
.157	650	.18
.158	675	.19
.159	700	.21
.161	800	.23

30 tests on this same size bar gave an average breaking load of 622 pounds.

loads varied from 590 to over 700 pounds. Mr. Keep replied as follows: "I did consider the high results obtained as due to your machine being out of order, but I was mistaken as my machine gives the same results. This iron is remarkably strong; I don't know of anything as good."

In great Britain we consider Mr. Keep knows all about the mechanical tests that American irons will stand. The results shown in Table II of tests made with the same class of iron as those dealt with in Table I are not only typical of results obtained by the author but of those secured by other workers.

The general practice differs somewhat between the two countries in regard to the allowable percentage of the chemical elements in different classes of gray cast iron. This is undoubt-

edly due to prevailing differences in the irons and not to a lack of metallurgical knowledge.

With one or two notable exceptions, practical foundrymen in America appear to pay little attention to total carbon. While carbon receives special attention and is frequently mentioned, it is only lately that total carbon has had due consideration. The quantity of combined carbon is important, but it is obvious that with varying amounts of total carbon the same percentage of combined carbon will have a different effect. Dr. Stead* has shown examples in which increases of 0.1 per cent of graphite have reduced transverse strength by 224 pounds and tensile strength by 1792 pounds per square inch.

Silicon receives a great amount of attention in American foundry practice and in conjunction with sulphur appears to be regarded as the Alpha and Omega by the purchasers of pig irons. One hears a great deal of "silicon control." In Great Britain silicon is merely considered with all the other elements entering into a commercial analysis. It must not be supposed that there is any lack of appreciation of the value of silicon, since in this city—the home of Professor Turner—it is probable that more research work has been done with regard to the influence of silicon than in any other center. A formula which the author has used for many years with marked success in connection with the ratio of silicon to carbon in gray cast iron mixtures is as follows:

$$X = \frac{C}{4.26 - \frac{Si}{3.6}}$$

where X=the ratio of silicon to total carbon.

C=total carbon present.

Si=Silicon present.

X=0.9 to 1 for such work as pipes, grates, easily machined castings and general ordinary work.

X=0.83 for locomotive cylinders and castings requiring *maximum transverse strength.*

X=0.76 to 0.82 for steam, gas, oil and diesel engine cylinders, and castings requiring *maximum tensile strength.*

X=0.75 to 0.8 for chilled castings.

X=0.85 for acid resisting castings.

*British Foundrymen's Association, 1915

What Is Effect of Sulphur?

At one time in this country sulphur was considered the arch enemy of the ironfounder, although probably it is not taken quite so seriously as it is in America. In his exchange paper George K. Elliott considers that sulphur above 0.07 per cent is dangerous. This does not agree with the results of Coe's* research on British irons. Coe found that sulphur within the

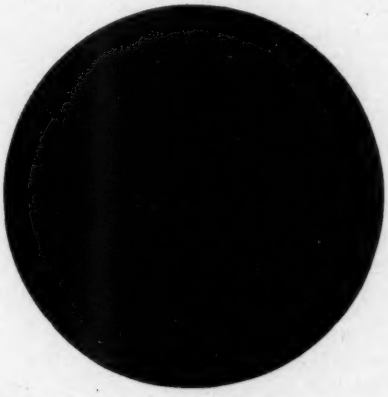


FIG. 3—GRAY IRON WITH TENSILE STRENGTH OF 20,384 POUNDS X 30
Graphitic carbon, 2.397; combined carbon, 0.853; silicon, 1.328; sulphur, 0.095; phosphorus, 0.923; and manganese, 0.290 per cent.

limits of his work did not increase the brittleness of cast iron but appears to increase resistance to fracture.

In Table I the sulphur appears in a proportion twice the amount which Mr. Elliott considered dangerous, yet it does not appear to have prevented a high degree of strength being obtained. A liberal proportion, up to 0.12 per cent, has in the author's experience been found to have a beneficial effect upon the wearing properties of cylinders and liners subjected to heat conditions while no difficulty has been met with in the way of blow holes provided the metal has been melted and cast hot.

To an appreciable extent phosphorus is considered in

*British Foundrymen's Association *Proceedings* 1911-12.

America to be detrimental to the strength of gray cast iron. George K. Elliott in his paper states "Irons of greatest strength contain only a small amount of phosphorus." Dr. Moldenke in *Principles of Iron Founding* appears to put the limit for strong castings free from strains at 0.4 per cent. The author's experience points to the conclusion that with the strongest British irons the *distribution of the phosphorus,* provided the amount does not exceed 1 per cent, is more important than the actual quantity present. Phosphorus in a segregated form, the usual form in all weak irons, is dangerous where strengths are required, but provided it appears in the network or cellular form no detriment to strength is experienced with phosphorus up to 1 per cent. This form is assisted so long as the silicon and total carbon are restricted in the ratio appearing in the formulas for strong irons.

Agreement appears to be more general in regard to the benefit to be derived from the poling action of manganese, but the author believes that manganese to the extent of 1 per cent or over is detrimental to good wearing properties under heat conditions. This element has a way of developing spiky crystals which break off under rubbing and prevent the formation of that highly polished surface generally regarded as the distinguishing characteristic of all good wearing cast iron. Apparently, there is much to be gained by keeping this element restricted to the proper proportion called for by the amount of sulphur present and for this purpose manganese should not exceed five times the amount of sulphur; beyond this proportion there is a danger of the formation of manganese carbide.

Although chemical analysis necessarily forms the basis of all scientific work in regard to cast iron, unfortunately it does not follow that similar analyses necessarily involve similar physical properties. It is also admitted that strong gray cast irons are associated with the matrix consisting of fairly large areas of well defined laminated pearlite, relatively stiff portions of cementite and small graphite, and these formations are illustrated by typical examples in Figs. 1 and 2.

While the microscope is a useful adjunct to chemical an-

alysis the utility of the micrograph is limited; it being impossible to determine therefrom relative physical properties of specimens with mathematical precision, or to ascertain within narrow limits the relative variations. In all probability this is due to our imperfect knowledge of both subjects and it may be hoped that further research will clear up some of these matters.

Occasionally, it is quite impossible in dealing with this

FIG. 4—GRAY IRON WITH TENSILE STRENGTH OF 40,992 POUNDS X 30
Graphitic carbon, 2.289; combined carbon, 0.903; silicon, 1.314; sulphur, 0.101; phosphorus, 0.909; manganese, 0.335 per cent.

class of iron to discover either by chemical analysis or the usual methods of microscopic examination great differences in physical properties. An interesting example of this took place some time ago. It was found that the highest tensile test obtained in 60 consecutive days' workings was lower than the lowest tensile test during the next 60 days. The metal was of similar chemical analysis but the mixture had been varied by introducing a different pig iron brand as one of the three constituting the charge. A research was carried out by the late George Hailstone and the author in connection with this class of inves-

tigation. All the methods usually employed for detecting the cause of difference in physical properties such as chemical analysis, high and low power microscopic analysis and the employment of various etching agents failed to show any reasonable cause for the great difference which existed.

As a further test, specimens were deeply etched with 20 per cent nitric acid in water as suggested by Stead* and afterward re-examined under low magnification. It was then found that the strength of the material was directly related to the particular formation of the cementite and phosphide eutectic. The stronger the iron, the clearer were these two microscopic elements in the network as shown in Figs. 3, 4 and 5.

The author has made many hundreds of examinations in order to test this and has never found a single example to the contrary. The network formation is apparent at about 26,880 pounds tensile strength and becomes more pronounced as the strength increases. In the author's view this method gives a surer approximation of the physical properties of the metal than any other form of metallography and is often superior to chemical analysis. It must be remembered, however, that the field under observation must be typical of the whole. In the illustrations given the micrographs are taken from the center of the bar.

In connection with the research already referred to the authors as one of their conclusions decided that the temperature at which the pig iron is made in the blast furnace has a direct effect upon the formation of this network structure. At the time this statement aroused a great amount of criticism, one professor stating that after remelting the iron had forgotten all about the hole from which it had been dug. Time has since proved the inaccuracy of this view and it is now clear that the temperature of the blast furnace has a marked effect upon the physical properties of the metal, and that these are maintained after remelting.

One progressive blast furnace manager has found that pig iron having this network structure, after going through the

**Proceedings,* British Foundrymen's association, 1908-09.

puddling furnace, yields wrought iron with higher physical properties than is to be obtained from a pig iron of similar analysis without this structure. He discovered further that with similar working and furnace burden the network structure was controlled by the blast temperature. When using a blast temperature of 900 degrees Fahr. he is always able to get the network structure; whereas if the temperature is increased the network diminishes until at 1100 degrees it disappears entirely with a corresponding lowering of physical properties of the wrought iron, the general chemical composition of the metal being the same. As the result of these discoveries the blast furnace manager has now fitted his furnace with pyrometers for recording the temperature of the blast and is able thereby to obtain more regularly consistent results.

Another criticism by a well known metallurgist was that although greater tensile strengths were associated with a net work formation of the cementite and phosphide eutectic he thought the metal would give less resistance to shock or fatigue.

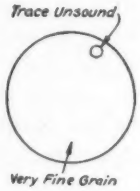
Rotary fatigue tests were taken by the Wheeler method by the Sheffield testing works on the bars whose structure is shown in Figs. 3 and 4 and these are given in Table III. Fig.

FIG. 5—GRAY IRON WITH TENSILE STRENGTH OF 44,486 POUNDS X 30
Graphitic carbon, 2.49; combined carbon, 0.72; silicon, 1.49; sulphur, 0.126; phosphorus, 1.2; and manganese, 0.420 per cent.

6 gives a general description of the method of applying the test and the dimensions of the test bar. The comparative results are even wider apart than appears from the tensile results.

Table III

Chemical analysis	Tensile strength, pounds per square inch	Rotary fatigue test results: Revolutions per minute	Fiber stress tons per sq. in.	Total number revolutions to produce fracture	Appearance of fracture
T.C. 3.25%					
G.C. 2.397					
C.C. 0.853		980	5	10,000	Fracture sound
Si 1.328	20384	980	6	9,200	Slightly open
S. 0.95					
P. 0.923				19,200	Grained
Mg. 0.290					
T.C. 3.192					
		980	5	10,000	
G.C. 2.289		980	6	10,000	
		980	7	10,000	Trace Unsound
C.C. 0.903		980	8	10,000	
		980	9	10,000	
Si. 1.314	40992	980	10	10,000	
		980	11	10,000	
S. 0.101		980	12	10,000	
		980	14	10,000	
P. 0.909		980	13	10,000	
		980	15	800	
Mg. 0.335					Very Fine Grain
				100,800	



The fundamental law governing the phenomena of the formation of the network structure has not so far been definitely and satisfactorily proved. J. E. Fletcher, however, has furnished an explanation which has the greatest degree of probability. Mr. Fletcher is advising director to the British Cast Iron and Wrought Iron associations and has devoted much thought and research to the elucidation of this problem in connection both with the blast furnace and the cupola.

He believes that this structure follows the original boundaries between the crystals of the metal which is first fused during the descent of the iron to the fusion zone in the blast furnace. The carburization of the crystals follows their boundaries just as decarburization follows them in the mechanism of the malleablizing process.

If the blast penetration effect while passing the tuyere zones

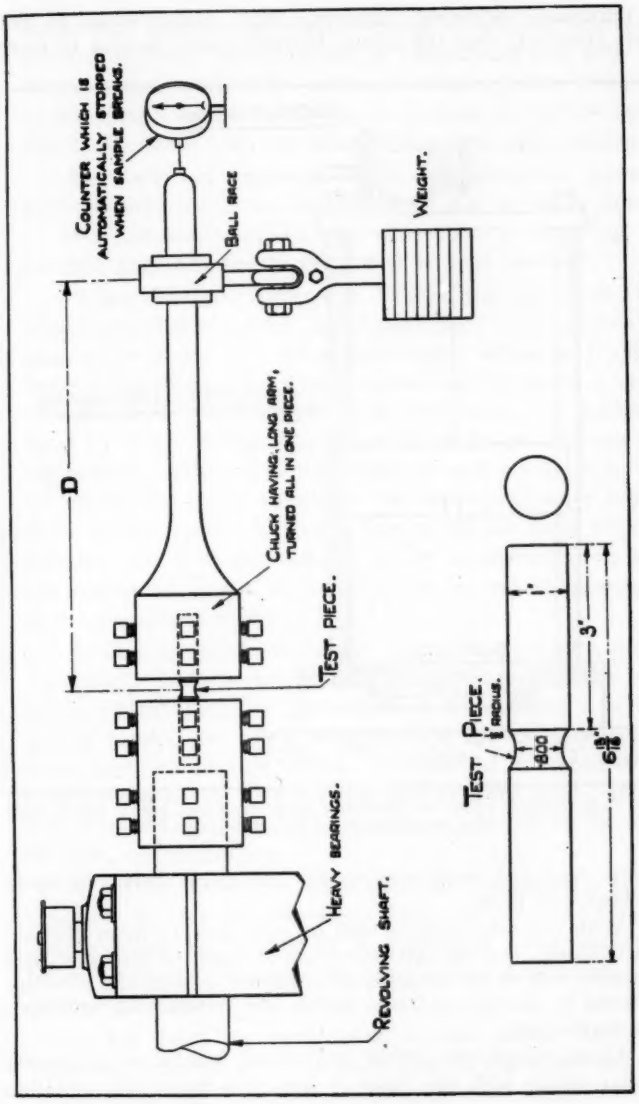


FIG. 6—METHOD OF APPLYING ROTARY FATIGUE TESTS

is drastically oxidizing, following rapid carburization in hot blast furnaces, then the strong boundary-intercohesion is more

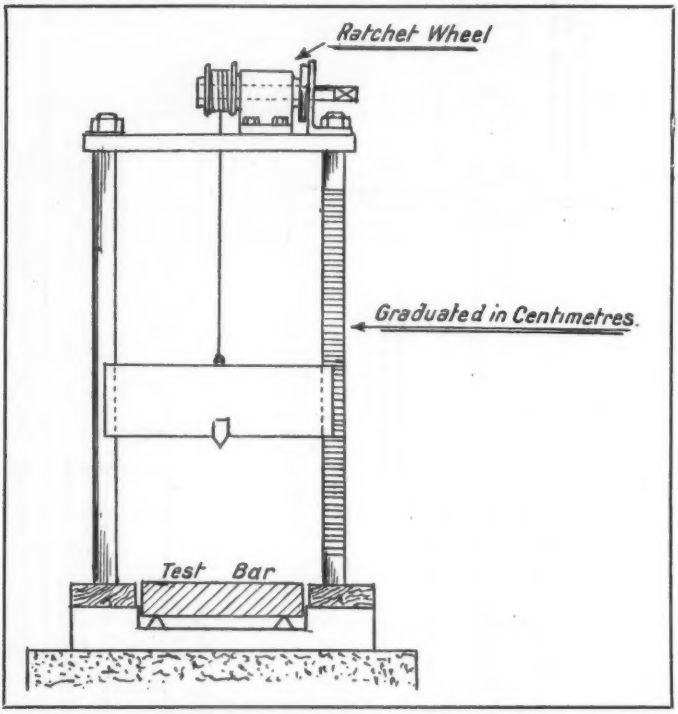


FIG. 7—MACHINE USED IN EUROPE FOR TESTING GRAY IRON FOR SHOCK RESISTING PROPERTIES

or less destroyed, with possible gas and oxide inclusions along the boundary films.

With the soft blast of cool or cold blast furnaces this action is absent, and the intercohesional strength of the crystalline structure, due to the presence of combined carbon and air—unimpaired by gaseous and iron oxides and minute slag inclusions—is maintained.

Points which the author has found helpful in producing regular results with this class of iron have been close attention

to chemical analysis and regular testing for general hardness by the drill method. But it should be remembered that with these strong irons a much stiffer machine is required than that known as the Keep's machine. Owing to its lack of rigidity the author's experience with this machine has been disappointing.

Regularity of hardness, which is a governing factor of high physical properties, is only attainable by strict attention to blast pressure, and in this connection a recording blast pressure gage attached to the cupola is most desirable.

A test becoming general in Europe for cast irons of the highest physical properties, more particularly in connection with casting for diesel and large gas engine piston and cylinder liners is the shock test. This is carried out by testing a bar cast 40 millimeters square supported on knife edges 160 millimeters apart by dropping onto it a weight of 12 kilograms from varying heights. Attached to the weight in such a way as to strike the bar in the center parallel to the supporting knife edges is fixed another knife edge. The face of all the knife edges are rounded to a 1/16-inch radius. So far as the author is aware this test is not in use in America. A general arrangement of such a machine is shown in Fig. 7.

In carrying out a shock test we commence with a drop of the weight from a height of 30 centimeters increasing the height of the drop by increments of 5 centimeters until the sample breaks, the height at which the bar eventually breaks being taken as the test figure. A result of 55 centimeters is considered none too high for the class of work named although it is quite a severe test. The maximum attained by the author has been 88 centimeters.

Mr. Wheeler uses the same sized bar and machine as a fatigue test, but for this commences with a drop of 28 centimeters and increases by heights of 1 centimeter. The number of blows required to fracture the sample should be taken as the fatigue test numeral.

A bar from the same metal as the tensile bar of Mr. Wheeler's referred to in the early part of the paper withstood 30 blows, having a range from 28 to 57 centimeters.

In conclusion if, as has been suggested in the first part of this paper, there is a wide difference in the strength of the respective gray cast irons, of which some particulars in regard to the British have been given, the author would suggest the query whether this may not be due to the slow running furnaces in Great Britain producing metal having better properties than that made by the large, fast running furnaces which appear to be general in America. Unfortunately even in this country, the slow running furnaces are diminishing in number.

The author's best thanks are due and are hereby tendered to Professor Turner for help with some of the micrographs and to Messrs. Bellis and Morcom for their permission to publish some of the results.

Appendix

To compare the breaking loads of two bars of similar material, but of circular and square section respectively, the bars being loaded at the center and supported at the ends, the length between the supports being the same in each case, let R represent moment of resistance of a section; Z, the modulus of section; f_b, the modulus of rupture (transverse); W_b, breaking load; and L, length between bar supports.

The bending moment due to breaking load $= \frac{1}{4} W_b L$

$$R = Zf_b$$

$$\therefore \tfrac{1}{4} W_b L = Zf_b \therefore W_b = \frac{4Zf_b}{L} \quad \ldots\ldots(1)$$

However the above formula is only correct within the elastic limit of the material. When test pieces are broken a constant arrived at by experiment has to be introduced:

Let $f_b =$ modulus of rupture as found by experiment.

Let $f_t =$ ultimate tensile stress as found by experiment.

Then from Lineham's *Mechanical Engineering*, page 436

$f_b = Oft$ where $O =$ a constant.

In the case of cast iron, $O = 2$ tons for rectangular sections and 2.35 for circular sections. Substituting Lineham's value for f_b in equation (1)

$$W_b = \frac{4Z \cdot Oft}{L} \quad \ldots\ldots(2)$$

Let $W_s =$ breaking load on bar of square section

$W_c =$ breaking load on bar of circular section

$Z_s =$ modulus of 1-inch square section
$Z_c =$ modulus of 1¼ circular section
} bending action

$O_s =$ constant for square section $= 2.$
$O_c =$ constant for circular section $= 2.35$
} for cast iron

ft is the same for both bars as they are of the same material. From equation (2)

$$W_s = \frac{4 Z_s O_s ft}{L} \qquad \text{and} \qquad W_c = \frac{4 Z_c O_c ft}{L}$$

$$\therefore \frac{W_s}{W_c} = \frac{Z_s O_s}{Z_c O_c} = \frac{2 Z_s}{2.35 Z_c} = .8509 \frac{Z_s}{Z_c} \therefore \frac{W_s}{W_c} = .8509 \frac{Z_s}{Z_c} \quad \ldots\ldots(3)$$

$$= \frac{W_s}{W_c} = \frac{.8509 \times .1667}{.1917} = .7399, \text{ say } .74.$$

Discussion—American vs. British Gray Cast Iron

By HORACE J. YOUNG, Wallsend-on-Tyne, England

The writer agrees with Mr. Cook in his opening statement that "The average British engineer considers that American gray cast irons of their respective class are inferior in physical properties to those of Great Britain." The writer thinks Mr. Cook has been generous in the way he has put it. After all it is a scientific matter, not a personal one, and it does nobody any harm to be plainly told that they are not doing quite so well as they appear to believe. As a matter of scientific fact American foundry literature frequently, nay, commonly, talks about very ordinary results as if they were things a little marvelous. Britishers have plenty to worry about and plenty to learn from America but on this particular point the American has something to learn from us.

Over in England we have two schools of thought upon the subject of what causes good tests. One of these schools puts forward the theory that some pig irons possess unalterable properties which are inherited by the cast iron made from them, while the other school of thought will not admit this—as a practical proposition affecting practical work—without scientific proofs. Mr. Cook, as is evident from his paper, belongs to the former school while the writer belongs to the latter.

Let America hesitate before adopting and applying this doctrine of inherent properties. Let her demand substantial and tangible evidence of it. As a scientist I put forward the following statement as one which cannot, I believe, be scientifically controverted—"In this country there are a few good people who will argue unendingly upon the existence of inherent properties in this or that, generally nameless, pig iron but never yet has anyone put forward a full record of many heats of two grey cast irons of precisely similar ultimate composition, one iron giving high tests and the other low tests, with nothing to account

for the difference save some inherent property in one or more of the pig irons used in the mixtures.

Few people appear to realize that a research on these lines would be a very large piece of work. The writer frankly admits, after eleven years of iron foundry practice, that he does not, at the moment, see how to set about it.

He has tabulated records of the ultimate analyses of several thousands of test-bars and out of all that number he has not yet found two bars of precisely similar composition—this is speaking only of combined carbon, free carbon, silicon, phosphorus, sulphur and manganese and is not taking into consideration the many other elements which could be estimated, apart from those which could not. Hence it is well to thoroughly absorb the fact that it is amazingly difficult to produce two cast irons of precisely similar ultimate composition, and it may be coupled with another fact, namely, that the correct analysis of cast iron is one of the most difficult problems in analytical chemistry.

It may be taken as proved that very seldom indeed do two test bars of cast iron possess precisely similar compositions; rarely ever, if they are cast from the same ladle; hardly ever, if they are cast with surface metal; probably never, if they are cast from different ladles or different mixtures.

A further difficulty, and an enormous one, is that of melting and casting two mixtures of iron under precisely similar conditions. The writer has for some months worked a cupola, with trained assistants standing at every point with every possible control apparatus and indicating instrument, yet he could not guarantee tomorrow to get precisely the same results from the same mixture of irons as he got last week—the word "precisely," as used here, must necessarily be taken to indicate such precision as will satisfy the requirements of scientific research.

How can one measure, far less control, the volume and pressure of air passing into the cupola every minute of the

run? What instrument will accurately measure air passing at the rate of that of the air supply to a cupola?

Again how can one control the height of the bed from the beginning to the end of the blow? One can control it well enough for average works purposes, perhaps; but well enough to say with scientific accuracy that on each occasion it remained the same throughout—No.

Atmospheric conditions must be taken into serious account, direction and strength of wind, barometric pressure, aqueous vapor saturation and temperature of the air—all of which are important matters and probably account in no few cases for the mysterious times when the foundryman says "my cupola is working slow, or cold, or hot, or fast today."

The rate of passage and the length of passage of the molten metal through the incandescent coke are very vital factors. One pig iron, by reason of no inherent properties, may behave differently to another pig iron and by so doing gives mysteriously different results. Such results may be, and very often are, caused by different size pieces of metal, by a difference in the condition and nature of the surface or in the amount of surface area, or in the way the pig iron was cast; also by the amount of combined carbon and of graphite and finally by its general composition.

The effects of temperature, time, mass and composition during the period the metal is standing in the ladle are very vital things almost impossible to control. It will be found that test bars cast with metal taken anywhere near the surface of the ladle have never the same ultimate composition as that of the main mass of metal in the ladle. The author possesses hundreds of analyses of test bars cast-separately-from-the-main-castings compared with test bars cast-attached-to-the-main-castings; in no instance are the compositions or the physical tests of the one comparable with or relative to the other. The test bars cast-separately, from the metal near the surface of the main ladle, differ most fantastically and their composition cannot be accurately predicted. It has long been the writer's opinion that the

greatest stumbling block to America's progress in ordinary gray cast iron is their tapered test bar cast-separately.

Control of casting temperatures and of cooling conditions present other difficult problems and it would be possible to go on enumerating further difficulties without serving any further purpose. It should, however, be evident to everyone that proofs of the inherent properties of pig iron are lacking as indeed are proofs of many of the things that we believe, or disbelieve, about gray cast iron.

For years the writer has used any and every pig iron that has come his way, choosing them by composition and by price. If he requires the composition possessed by certain cold-blast irons he has to buy them unless he succeeds in obtaining that composition without their use. He has not yet observed any inherent property in any pig iron—admittedly there are many brands that he has had no experience of—when he does observe it he will set to work to produce and publish the proofs of its existence. In the meantime he feels certain that any average American foundry could produce precisely the same results as any average English foundry, each using their own irons and each observing the ultimate composition of the pig iron and scrap iron and controlling that of the cast iron. He feels that there is no difficulty at all about it and he himself would, with the greatest possible confidence, undertake to prove it without any question of pig iron possessing, or not possessing, inherent properties.

Of course the American foundryman, like his British brother, will need to put behind him all prejudice regarding composition. There are two subtle facts which American foundrymen can easily make better use of than has the average British foundryman. Firstly, scrap iron or remelted iron has a different composition to that which it had before it was melted in the cupola; secondly, many of the best cold-blast or semi-cold-blast or white pig irons have different compositions to any other pig irons—these two facts contain many lessons of value to the inquiring foundryman provided he will bury his prejudices.

It is more difficult to get a high strength from gray cast

iron containing over, say, 0.6 per cent of manganese than from an iron containing rather less—other things being equal in each case. It is more difficult to get a high strength from gray iron containing less than, say, 0.09 per cent of sulphur than from iron containing rather more—other things being equal in each case. To a greater or lesser extent can similar remarks be made concerning carbon, silicon and phosphorus. The length and breadth of the subject are almost infinite and our present knowledge is very minute, but if the foundryman insists upon working upon a range of compositions from which it is more than usually difficult to get high tests then he will be unlikely to get them in the ordinary run of events.

Mr. Cook puts before you the highly interesting phenomenon of the phosphide (and sometimes phosphide-cementite) network as discovered by him and the late George Hailstone. Here is not the place to discuss the explanation of the network structure as given by those authors, sufficient to say, firstly, that poor network is usually associated with poor physical tests and vice versa, and, secondly, that the writer has had many instances of both poor and good network arising out of perfectly tangible explanations such as, for instance, a wrong sulphur-manganese balance which balance, at the point of equilibrium, is hardly to be detected by ordinary analysis. On the other hand the writer has never seen proofs of poor and good network being caused by inherent properties of the pig iron used nor has he ever seen any paper which satisfactorily, exhaustively and scientifically proved a case of this kind.

In conclusion, therefore, the writer expresses his opinion that the inherent property theory, even if correct, is no explanation as to why the tests of American cast iron are on the low side and he believes that just as high tests could be got from average American pig irons as from average British pig irons—this being true in all cases save those where it it absolutely imperative to obtain the particular composition possessed by one or other brand of iron, American or British, and where it cannot be obtained by the use of other brands.

Undoubtedly in our present state of knowledge about cast

iron we must be prepared and willing to revise our present ideas—but only upon the most reliable and exhaustive evidence.

Extremes of thought have led to extremes in practice, and occasionally American practice gives one the idea that it is a little on the extreme side—low sulphur and high manganese, for instance, are quite reasonable propositions but, except in extreme cases, there seems to be no advantage to be obtained from extremely low sulphur or extremely high manganese (or vice versa) while in extreme cases, where such compositions must be worked to, one frequently meets with trouble.

This contribution is by no means a criticism of Mr. Cook's paper but is sent solely with the idea of stimulating international discussion and thought upon a subject of great interest. Mr. Cook and the writer have compared notes before now and find remarkably little to argue about when we get down to rock bottom—to get there and to know when you have got there are scientific problems in themselves.

Discussion—American vs. British Gray Cast Iron

By G. K. Elliott, Cincinnati, O.

It is with the closest interest that I have read this spirited and wholly praiseworthy exchange paper. As an international paper it is admirable because of the insight it gives Americans into important points of British gray iron metallurgy, and because of its very attractive controversial possibilities. The paper cannot help but redound to the great good of gray iron theory and practice in both Great Britain and the United States.

There are two kinds of iron castings, those made from appropriate iron especially formulated for the particular casting, and those made from common nondescript cast iron which while broadly useful is not generally a felicitous choice for particular requirements. We suspect that Mr. Cook is comparing, in parts of his paper, British iron of the first class with American iron of the second. If our British friends have found some American machine tool castings faulty it is possible that they belonged to the last class; especially would this be true if said castings were made under stress of war conditions when some manufacturers found their own foundries too small and were forced to let out a part of their castings with a lack of discrimination that often was unavoidable. In this country as in England it is probable that machinery builders who make their own castings have the iron under intelligent control, producing castings equal in every way to the demands of the intended service. I am a persistent advocate of specialization in foundry irons and therefore hail this part of Mr. Cook's paper with special satisfaction because it adds emphasis to a point all too little realized in some engineering circles. There is far too much needless obliquy attached to cast iron simply because a few manufacturers

through either ignorance or carelessness are habitually allowing questionable grades of iron to enter into important castings.

Mr. Cook mentions the reported failures of cast iron parts in America under exposure to superheated steam. This phenomenon of growth and warping under superheated steam has been referred to by American writers with more frequency and emphasis than is justified by the instances of its occurrence. A search of technical literature shows that the most of the references go back either directly or indirectly to three papers read before the American Society of Mechanical Engineers over twelve years ago. The number of cases reported since then is very small. Those mentioned are not to be denied but my long experience in this line convinces me that when fittings intended to handle superheated steam are made from appropriate iron the danger of failure is remote except possibly where most uncommonly high degrees of superheat are used. I have yet to see the first valve or fitting made of suitable iron that has failed under this service. It is certain that cast iron parts made by American manufacturers specializing in this line and making their own castings, are made of iron entirely capable of encountering successfully the feared but somewhat overestimated superheat peril.

High Strength Symbol of Special Iron

The average of over 36,000 pounds per square inch tensile strength attained by Mr. Cook bespeaks the sterling foundryman and suggests that his iron falls within the category of special irons; at least it would be unfair to set it up against iron of the common variety. Quite interesting in this same connection would be a record of strengths of irons melted in the average English jobbing foundry. I myself have seen many hundreds of heats of iron run without the aid of steel additions, having an average tensile strength corresponding almost identically with that obtained by Mr. Cook; the iron, however, was formulated for a particular purpose and should not be compared ser-

iously with the product of the ordinary foundry catering to a not fastidious trade. Mr. Cook's tensile and "arbitration" strength in Table I are highly commendable but should not reflect unfavorably upon American iron because his bars were cast on the main castings while the arbitration bars were cast separately. It is well known among foundrymen that test bars can be located so favorably in relation to the main casting, when "cast on," as to give great advantage to the bars even to the extent of giving a grossly exaggerated indication of the true strength of the iron in the main casting.

Comparing Arbitration Bars

The attempt to reconcile the strength of the 1¼-inch round American arbitration bar with that of British one-inch square bars by use of the factor 0.74 is not to be commended because no account seems to be taken of the quite different manner in which square and round section bars form crystals while cooling. Mr. Cook used this same device in his very able and keen discussion of my exchange paper before the Institution of British Foundrymen last year which is referred to by him on page 122 of the present paper in this volume where he calls attention to the fact that his lowest "equivalent load" (evidently obtained through the 0.74 factor) was higher than the transverse strength of electric furnace refined iron mentioned in my paper. Mr. Cook seems to take it for granted that the strengths mentioned in my paper were exceptional for American iron. This was far from being the case; they were not given as being the last word in cast-iron test-bar strengths but rather as illustrations of the improvement wrought in irons of somewhat lowly origin by treatment in the basic-hearth electric furnace. The strengths were shown in pairs so as to depict the same iron before and after treatment, and so doing fulfilled their only mission of showing that the process materially improved the original cupola metal. That the strengths were in any way exceptional was not claimed. Purposely did I avoid injecting the phenomenal into the

paper which fact does not seem to have been understood by several British commentators.

In the case of carbon in cast iron, I am sure it will be found that more iron foundries in this country pay attention to it than Mr. Cook suspects. These naturally do not include the great rank and file of unspecialized foundries already mentioned but only such as make the better grades of castings. In making fittings for superheated steam for instance certain foundries pay great attention to the amount, the size and the distribution of the free carbon.

Effects of Sulphur and Phosphorus

The sulphur question is taken up in the paper and it is safe to assume that this is one question that never will be settled to the satisfaction of everybody, especially of persons who through geography or economy are somewhat inescapably tied fast to high sulphur. To a less extent this also is true of phosphorus in considering which Mr. Cook makes the important observation that its distribution is of utmost importance, that segregated phosphide is more dangerous than the uniformly distributed. It is my belief that high phosphorus and high sulphur will become less dangerous only when foundrymen learn a way to produce without fail, both phosphides and sulphides in a certain *optimum* degree of dispersion and of a certain critical particle size.

I do not believe that foundrymen have yet learned the way to do this but discussions such as Mr. Cook's will aid greatly in throwing the desired light upon the subject. As matters now stand it seems that sulphur and phosphorus are safest when absent.

Use of Dynamic Tests

I am much pleased to see Mr. Cook refer to tests of a more dynamic nature than the usual tensile and transverse tests. It is to be hoped that a more general adoption of dynamic or shock tests is near at hand for I

believe these tests will greatly increase our knowledge of the differences between irons now apparently the same as far as the usual static tests go and yet which do not show up the same in service. I have in mind two sets of valve body castings weighing about six hundred pounds each that were broken up under a foundry drop-weight. One set was made from iron having about 0.08 per cent sulphur and an average of two drops of the weight was necessary to break each casting. The other set was made of the same iron but refined in the electric furnace, with sulphur at about 0.035 per cent; these castings required four or five drops each to be broken. By transverse tests the second iron was about thirty-five per cent stronger than the first; by the drop test it was over a hundred per cent stronger.

Effects of Hot and Cold Blast

The theory advanced in the paper and attributed to J. E. Fletcher, concerning the relative effects of hot and cold blast furnaces upon the structure and properties of gray iron, is, by way of contrast, strongly suggestive of the thought advanced by the late J. E. Johnson in his theory of oxygenated iron. Johnson's theory is that the cool running charcoal blast furnace causes a certain marked oxygenation of the iron which condition in turn, he contended, effects a compactness of the graphite formation that is not to be found in the product of the hotter running coke blast furnaces. On the other hand Mr. Cook bases his claims for superiority in the iron from the cool running furnace, upon a quite different assumption, that through ***lack*** of oxidizing conditions a certain boundary-intercohesional strength is preserved in the metal.

Theories on Cool Running Furnaces Conflict

In view of the explanations of Messrs. Cook and Johnson, we are now confronted with two theories, both touching upon the question of oxygen and both claiming excellent properties in iron made in cool running blast furnaces. One

however, attributes the superiority to oxygen picked up under the named conditions while the other declares the iron to be superior because the same given conditions are not favorable to the taking up and retention of oxygen. Both theories touch upon fundamentals of the greatest interest but neither is convincing and we feel justified in demanding more and better evidence.

Discussion—American vs. British Gray Cast Iron

By R. S. MacPherron, Milwaukee, Wis.

The interchange of ideas between the two countries, as brought about in exchange papers, is always interesting as well as profitable. Mr. Cook, in particular, has advanced a number of original and unique ideas. It is a great pleasure to note his development of the metallography of cast iron. This is as complex as that of steel and has not received sufficient attention. If it were possible, we would be very glad to examine one of their specimens of cast iron in order to see just what he means by the distribution of phosphorus. Some of us have always believed that phosphorus to the extent of 1 per cent has an unfavorable action on the physical properties of cast iron.

It is unfortunate that he limits his comparison of physical properties to irons made without the addition of steel in the cupola. This is the common practice in most American foundries and is the method by which we usually make our high test irons. He can not mean to criticize our material and then exclude from consideration or comparison our best grade. We note that he quotes from only one grade of irons. It would be interesting to know if they use the same grade for all castings.

Referring to his comments on transverse and tensile strength, it must be said the results he shows are extremely good, probably better than most foundries in this country would show. It is difficult to compare tests on transverse bars of various sizes. It is our practice to use a bar 1 x 2 x 24 inches between supports, broken with flat side down and loaded in center. In the last three months, we have tested 55 sets of such bars for an inspected job, with average transverse load of 3055 pounds and the deflection of

.54 inches. On one recent order, the 82 sets of tensile bars cast for the job averaged 32,700 pounds per square inch. On another similar order, the 85 sets of tensile bars averaged 33,670 pounds per square inch. All our bars are cast in separate molds and the tensile bars are cast 1⅜ inches round by 14 inches long. The ends are rough machined and middle of bar turned to about 1 inch in diameter for a space of 2 inches.

The above bars represent all the tests made and were not selected for their high value. They represent our medium grade material and not our hardest grade material from which we made our cylinders, liners, etc. Transverse bars of this latter mixture (1 x 2 x 24 inches, as above) have gone as high as 4280 pounds. This would be considerably over 40,000 pounds per square inch in a tensile bar.

Two tensile bars recently cut from the bore of a liner for our 48 inch diameter gas engine cylinders broke at 36,080 and 36,480 pounds per square inch. This liner weighed about 5000 pounds in the rough with a metal thickness of about 1½ inches. The brinell hardness of the casting was 183 taken on finished bore. A photomicrograph of this metal is shown in the accompanying illustration.

Another bar just cut from a full sized prolongation of a 44 inch diameter gas engine liner showed 37,960 pounds per square inch. The hardness of bore after machining was 192. This casting weighed 4300 pounds in the rough with metal thickness of nearly 1½ inches. These tensile bars were turned to .25 inch diameter with threaded ends. In view of their being cut from a large casting, we feel these tests represent as good material as any to which Mr. Cook refers.

It might be stated that while we have made tests of our Class "A" iron showing over 40,000 pounds to the square inch, we do not make many tensile test bars for castings made from this mixture. The test bars are apt to be mottled and extremely difficult to machine. In place of so many tensile bars, we are now making more hardness tests on the finished castings. It might be noted in this connection, that

the length of wear of cylinders or liners is not determined by their tensile strength, but by their hardness and closeness of grain. Another reason why the tensile test bar is not more used in this country is that the cost is over twice that of a transverse bar.

We would be inclined to agree with Dr. Moldenke in his statement that the average tensile testing machines in this country do not pull absolutely in line, which naturally reduces the reported tensile strength.

The question of fillets is of extreme importance. Some time ago, one of the A. S. T. M. committees on cast iron, found that by making the fillet on our standard cast iron test bar much easier, the tensile strength could be increased by an average of over 3000 pounds to the square inch. This change, I believe, will soon be officially adopted.

Referring to the diagram shown on page 131, the writer knows of a machine of this type that has been set up in a neighboring foundry for 20 years. It varies from that mentioned by Mr. Cook, only in being graduated in inches and the weight being dropped by a trip.

There is no doubt that many of our American castings are made too soft. On this point, I believe we are open to criticism. Too much attention is given to ease of machining. This has been done purposely, however, and not because it was impossible to furnish close grained and strong material.

In regard to breakage of American made flywheels, I wish to quote the power department of the Allis-Chalmers Mfg. Co. as follows:

"The practice of the company is to run cast iron flywheels for engines up to a peripheral speed of 6000 feet per minute. During the past 45 years, we have built more than 7000 engines, aggregating over 6,000,000 horsepower. During this period, we have had only two or three reported flywheel failures which in each instance were directly traceable to overspeeding due to some breakage or failure of the governing devices.

In our saw-mill practice, the standard peripheral speed of cast iron band saw wheels is 10,000 feet per minute with

occasional speeds of 11,000 feet per minute. None of the several hundred wheels of this type built within the past 20 years have failed in service and but one or two, after periods of 15 to 17 years' service have required replacement due to local conditions. Outside of the experience of the Allis Chalmers Co., it would appear that the flywheel failures in America as a rule have not been due to the quality of the material, but either to overspeeding due to failure

FIG. 1—PHOTOMICROGRAPH SHOWING METAL OF A 48-INCH ENGINE LINER. TENSILE STRENGTH 36,080 POUNDS PER SQUARE INCH. MAGNIFICATION 400 DIA.

of the engine governors or to bad design of the wheels themselves."

We are greatly interested in his statement or question as to whether a slower running of the blast furnace and also lower blast temperatures would not tend to increase the strength of the castings made from resulting pig iron. It is common belief that warm blast charcoal pig iron is not as strong or as good as cold blast and it is quite possible that warm blast coke iron might be of better quality than a hot blast iron.

In referring to Mr. Cook's belief that the American practice is to regulate the mixture entirely by silicon content,

with no reference to total carbon, would say that this can hardly be the case, as a large percentage of American foundries purposely reduce the total carbon by adding steel in the cupola, which is apparently not the English practice.

We are inclined to agree with what Mr. Cook says about the influence of sulphur. In times past the influence of this element has been much over-emphasized. However, the specifications of the A. S. T. M., allow sulphur up to 0.12 per cent which is considerably in excess of 0.07 per cent as desired by G. K. Elliott. I have seen any number of good gray iron castings, containing from 0.15 to 0.18 per cent sulphur. As Mr. Cook says, manganese in these castings should be fairly high.

Discussion—American vs. British Gray Cast Iron

By Richard Moldenke, Watchung, N. J.

The criticism against American castings contained in Mr. Cook's highly interesting paper is unquestionably merited, but the conclusions are unfortunately based in greatest part on iron made here during the war. Those days are still a nightmare to our foundrymen, who had to use inferior pig irons when they could get pig iron at all; had to melt with coke made from the sweepings of the coal mines; use inefficient men who called themselves molders; and work with organizations that were shot to pieces. One has but to compare the present day sulphur content in our scrap with that before the war to understand what has happened. However, apart from the deplorable metal situation we find ourselves in, and which is bound to become worse as time goes on and the war castings find their way into the scrap pile in increasing quantities, our general practice undoubtedly is to make softer and weaker castings than our British cousins. The reason is not hard to find. Europe makes castings to last. America makes them to machine easy. Europe does not pay machinists American wages. America does not want a machine to outlast its usefulness particularly. We do not point with pride to a lathe or planer of fanciful design, painted in green and striped with gold, possibly of 1868 vintage, which is still too good to scrap. On the other hand, however, our foundry foremen may not have the satisfaction their British brethren enjoy when they make reply to a regular machine shop "holler" about hard iron. So much for the divergencies in practice made necessary by circumstance, and impossible of change in either British or American foundries.

That British furnaces run slower, and hence give better—and as I claim, less oxidized—pig iron than Amer-

ican furnaces, is undoubtedly true, for British irons would otherwise not have had as high a reputation in Germany as they enjoy. Again, our New England foundrymen would not be so desirous of getting scrapped English cotton-spinning machinery for their mixtures. However, we still have furnaces which make fine iron, and produce lines of castings equal to any in the world. Americans are prone to publish their failures freely, in the belief that this stimulates discussion leading to overcoming the difficulties, and opening avenues for invention and advancement. I have myself more than once run across parts of machines built in Europe, the broken pieces of which showed just as healthy shrink-holes as our castings. We have all of us still a lot to learn.

When it comes to a discussion of mechanical testing, I must confess that I am somewhat puzzled at the summary of British practice, as presented by Mr. Cook. With us here, the Keep method is considered so antiquated that it may only be found sporadically in stove shops as yet. With all due respects to the attainments of Mr. Keep, whom many of us remember and whose friendship we valued highly, none the less his usefulness as a guide ended when he refused to adjust himself to the for him uncomfortable facts brought out by foundry metallurgy. Possibly it is this study of cast iron in the light of the engineer, rather than as engineer and metallurgist, that makes me wish Mr. Cook had explained why Britain still uses square and flat bars, cast horizontally rather than round ones cast vertically. You have only to do as I have done—slice the flat bar in three, longitudially, and test each unit, to see how different the metal at the corners and edges is from that in the middle. We still have left one branch of the foundry industry using a flat bar, and this industry is now considering the advisability of getting up to date.

Looking over some of the strengths quoted by Mr. Cook, with analyses given, we are rather prone to explain the results by the remarkably low silicon content combined with pretty low total carbon conditions. We get the same

strengths here under the same conditions. That he does this regularly, and we but sporadically, and only when wanted, entitles him to our best congratulations. We wish we could do this all the time too and have peace with our machine shops.

As to the tensile test, it seems that the engineer who is accustomed to working with the elastic limit of materials, needs must have his values in tensile strength figures to understand them, even if he has to convert these figures later to transverse strengths. The foundryman, on the other hand, knows that cast iron is rarely used under a direct pull, but has to stand bending application. Hence he naturally gravitates to the transverse test. Yet this is really a tensile test of the outer fibres of his bar. Mr. Cook has mentioned my objection to the tensile test as our machines are not reliable. This has changed very much for the better, as our present day machines are arranged for a cast iron test piece with proper threaded ends as called for by the now universally used arbitration bar of the American Society for Testing Materials, and the American Foundrymen's Association, jointly. Formerly a bar of cast iron was simply inserted in the "V" grips of the machine, and the results almost always came out low.

The question of a proper international test bar is now being studied here carefully, and it is to be hoped that early conferences may take place looking toward interchange of facts and thoughts between Britain and ourselves, this to extend to the other European nations as rapidly as they may be willing to cooperate.

Mr. Cook is unquestionably right in holding that we have overrated the bad effects of sulphur. Possibly this is so for just the reason of our weak castings as against their strong ones. At any rate, we here fear the effect of shock, and this is notoriously connected up with the sulphur content. We have now become alive to the importance of oxidized metal as being far more dangerous than high sulphur, and knowing more of rational cupola practice now than we did some years ago, our sulphur has gone

higher without serious consequences because our better melting practice has allowed this. As Mr. Cook has not touched upon this phase of the foundry problem, it is not easy to follow his studies on the physical structures of cast iron. In addition to the analysis—oxygen being unfortunately not yet part of a regular analysis—a diagnosis of the iron for pig and scrap proportion, the melting history, approximate pouring temperature, and other things are necessary to understand the product made.

We are very much indebted to Mr. Cook for giving us the present status of British practice with regard to cast iron, known only to those of us who have been over there recently. His remark that even over there the furnaces are beginning to force production, and thereby lowering the quality of their product, leads me to think that possibly some day the foundryman will force the production of better iron by paying for it, and eventually the sheep will be effectually separated from the goats in furnacedom, so far as the foundry is concerned.

Discussion—American Versus British Gray Cast Iron

By S. B. PHELPS, Pittsburgh, Pa.

The paper, "American versus British Gray Cast Iron" by Mr. F. J. Cook is extremely interesting. The paper contains many statements, however, that American foundrymen and engineers know to be incorrect if it is inferred that the inferior castings cited represent standard American practice. The statement is made that large quantities of machine tools sent over to England during the war had poor wearing qualities and that it was said that "the cast iron was so soft as to be easily cut by a pocket knife." Certainly castings of the grade mentioned were not made in foundries which generally supply the machine tool trade, and they must have been made by foundries unfamiliar with the requirements of machine tool parts.

The following statement is also made, "Recently, some improvement has been noticed attributed partly to wider bearing surfaces, and the application of chills on wearing parts, combined with the use of semi-steel."

The writer was the melter in a foundry in a machine tool center several years before the war, and melted 50 to 60 tons of iron per day for the machine tool trade. Several grades of iron were made, as well as semi-steel for parts subject to wear. In addition, chills were used very liberally on surfaces subject to excessive wear. The grain of the iron and its hardness received special attention, and frequent trips to the machine shop were customary as one method of keeping in close touch with the quality of the products. The practice mentioned was not an innovation at that period, but was general practice. The writer has seen the same care taken in other foundries making machine tool castings.

Quite a number of new foundries and machine shops were started during the war, and all kinds of foundries were asked to make castings regardless of their knowledge of the required

products. That no doubt resulted in products in many lines being made below the usual standards. The emergencies of the war not only brought many novices into industrial business, but it interfered seriously with the quality of the output in industries of long standing. Coke, sand and metals were extremely difficult to obtain and the grade was often unfitted for the products that had to be made regardless of standards.

The writer was superintendent of a foundry during the war which was asked to make castings for a machine tool company. The mixtures used in that foundry were not suited for machine tools and the foundry organization previous to the writer's time was not familiar with machine tool requirements. It naturally occurred to me then that machine tool companies would have difficulties, if they were obliged to buy castings of any foundries that could make deliveries regardless of their lack of the special knowledge needed to produce strong machine tool castings with good wearing qualities. For long periods I had to forget about mixes for our castings, and mixed mostly by fracture and observation of the product as it was useless to get an analysis for we could not get the proper pig iron. The analysis of one carload of coke showed 20 per cent ash and we had to use it or shut down. If we had shut down we would have lost our force for the labor turnover was very high anyway, so we used the coke for several days and specialized on the "standing order" for scrap.

Probably such information will explain to British foundrymen some of the reasons for the production of some castings of poor quality during that critical period in world history when it seemed that the map of Europe was to be redesigned to suit the central powers.

Cupola Melting Tests, with Mixtures Changing During Run

By Richard Moldenke, Watchung, N. J.

As the foundryman oftentimes is confronted with the necessity of running special charges in the first part of his heat to turn out castings of a different character than his regular line of production, he will be interested in knowing what are his chances of keeping the several mixtures separate. The comparatively higher labor costs in America preclude the running of a series of small cupolas, each with its own mixture, as is done in Continental Europe, and hence the single, large cupola must serve with what protection a double coke charge between the mixtures will give.

It is quite common to find two mixtures run in the day's heat, and occasionally one finds three of them, depending upon the lines of work to be cared for. The smaller tonnage is always put through first, to get it out of the way, and if there are two mixtures for small amounts to be handled, the harder one is charged first. As such extra mixtures usually contain steel scrap—some of them high percentages—it is advisable to make the first charge one without steel or fine scrap. In the first case the melting steel falling upon the cold bottom will surely stick, and in washing away as the heat progresses affect the succeeding charges unfavorably, apart from giving the first ladle of iron without much benefit from the steel used. In the second case, with fine scrap in the mixture this will melt quickly and drip down on the bottom before the heavier sectioned iron melts, and thus give an erroneous impression of the height of the bed by yielding a flow of molten iron several minutes too soon.

With the first charge out of the way and the bottom well heated by this iron, and the second charge with its steel first, pig next and lighter scrap on top in uniformly spread layers, an even melting should take place as far as this may be carried out in the cupola process. Placing at least a charge and

a half, if not a double charge of coke between mixtures, and pouring the transition metal into work that will be satisfactory with both mixtures, a reasonable degree of success can be attained.

However, foundrymen will have noticed that the separation of the several mixtures is not nearly as effective as can be wished. For instance, where several charcoal iron charges, having a low phosphorus content, are put into the cupola first, and after putting on a double coke charge, the subsequent higher phosphorus iron charges go on up to the charging door, it has been noticed that the phosphorus content of almost the first iron is higher than it should have been. This shows that some of the upper charges must have melted along the lining of the cupola, and contaminated the purer iron of the lower charges. Instances of hard iron where soft was expected, and *vice versa* are common knowledge in the foundry. The analyses in a series of tests recently made with Mayari pig iron, which contains nickel-chromium, showed this intermingling of charges so plainly that it was deemed important enough to present to the foundry industry in form of a short report.

An extended research was made for the Bethlehem Steel Co. on the characteristics of their Mayari pig iron, made from Cuban ores carrying nickel and cromium. The composition of this pig iron runs about as follows:

	Per Cent
Silicon	0.50 up to 3.00
Manganese	0.90
Sulphur	0.03
Phosphorus	0.065
Nickel	1.20
Chromium	2.40
Titanium	0.18
Vanadium	0.05
Total Carbon	4.00

From this composition it will be seen that the nickel-chromium content is a prominent characteristic, and being so different in this respect from any other pig iron of the country, it is easily traced in its behavior in the cupola by the analysis of the metal made. With titanium reduced from the ore, and an almost negligible sulphur and phosphorus content, for cast

iron, this pig iron stands out as rather exceptional. It is gratifying to know that about 500,000,000 tons of this ore is in sight on 25,000 acres, in Cuba.

In the research above mentioned, almost every combination of the elements in iron, as used in the foundry, was to be tried out. The great slump in business necessitated a general cut, but nevertheless 245 separate tests were made with 1155 bars. These were made in the crucible, after 36 tests, with 135 bars therefrom, had been made in four foundries melting four to five separate mixtures ahead of the day's run in each case. The highly interesting results of the crucible tests will be published as a separate monograph, while the results of the cupola tests will be gone into here, to show how unreliable the cupola melting process is for exact melting results, despite its advantages for cheapness and simplicity in operation.

In making up the charges for the cupola, the first one was arranged to contain no Mayari pig iron at all. The second charge, separated from the first one by twice the amount of coke needed, or using a ratio of 5 to 1, instead of 10 to 1, contained 10 per cent Mayari pig iron. The third charge had 15 per cent Mayari, and was similarly separated from the second charge. The fourth charge had 20 per cent Mayari iron, in similar manner. Where a fifth charge was run, this consisted of whatever mixture was found convenient, usually with steel to reduce the total carbon. It will be seen, therefore, that the charges were much more widely separated than would have been the case in charging the same mixture, repeatedly, and therefore, melting could be expected to be fairly separate. It was only after the trial was made in foundry after foundry, that resort was had to the crucible department of the Bethlehem Steel Co., which generously detailed an entire unit of its large regenerative furnaces, holding 24 crucibles at a time, for this purpose.

In order to have the results as comparable as possible, even the scrap used was first made by remelting a standard pig iron in 5 ton batches. A mixture of 60 per cent pig and 40 per cent scrap was used in every case, the Mayari pig iron forming part

of the pig, when it was used. The laying out of the mixtures need not be gone into here; it is sufficient to say that every effort was made to have the program as exact as this could be made consistent with ordinary foundry routine. The charges varied from 600 to 2,000 pounds each, depending upon the cupola of the particular foundry. The surplus metal went directly into castings. Two sets of cores arranged for three test bars each were poured off for each mixture, the cores being parked together and rammed up in a flask. The A. S. T. M. arbitration bar, 1¼ inches diameter, and 15 inches long, poured vertically, was used, being afterward tested for transverse strength and deflection on supports 12 inches apart, for tensile strength, and for hardness by the Brinnel test. Micrographs also were taken. A complete analysis was made for each set of bars of a mixture.

The following figures summarize the results:

Charge No.	In Mixture Ni.	Cr.	In Castings Ni. Range	Ni. Aver.	Cr. Range	Cr. Aver.
1	0.00	0.00	0.08 to 0.12	0.10	0.16 to 0.24	0.23
2	0.12	0.24	0.09 to 0.13	0.11	0.23 to 0.37	0.28
3	0.18	0.36	0.08 to 0.11	0.10	0.23 to 0.30	0.27
4	0.24	0.48	0.08 to 0.12	0.10	0.23 to 0.38	0.28

From this table it will be observed that with perfect bed conditions in each of the four foundries, "first iron" over the spout coming in 10 minutes in each case, and with twice as much coke between the charges as need have been in ordinary practice, yet the Mayari pig iron must have melted, (and the other pig irons—also machine cast—with it) from the upper charges before the lower ones were gone. The above figures are the averages of a series of melts in each of which the regular progression of charges contained the nickel-chromium content as stated. What would have been the result had the usual 10 to 1 ratio of metal to coke been used, can only be conjectured. Melting could not have taken place within the middle of the upper charges as the only oxygen likely to be present above the melting zone would be close to the lining of the cupola. That melting does take place far up in the cupola at the lining is often observed by the foundryman when the nature of the scrap keeps the charges open. Thus, in making

brake-shoes with heavy percentages of stove plate scrap, and where on occasion an entire stove finds its way into a charge, iron can be observed melting a foot or two below the charging door, with the entire rim of metal red hot.

The only conclusion to be derived is that melting takes place much higher than is supposed, along the lining, and that it is of utmost importance to charge metal and scrap uniformly in their several layers, so that whether melting takes place in the upper charges or not, whatever does drop down will consist of the right proportions in the mixture. Again, that strict attention be paid to the order of charging—steel first, pig and heavy scrap next, and light scrap on top. Machine cast pig melts faster than sand cast pig of equal sections, because of the higher combined carbon in the first. Inasmuch as machine cast pig usually has a heavier section, this condition of melting usually equalizes itself.

Further, the practice occasionally met with of placing all the pig of a mixture around the rim of the charge, and the scrap in the center, cannot be condemned too severely. Cupola melting differs from all other methods in the peculiarity that intense heat is developed at the actual contact point of coke and iron. With the usual layering in charging, the proportion of coke to pig iron at the rim with the above mentioned practice, will be considerably smaller than it is in the middle, and hence coke will burn away too fast around the sides to give very hot metal, not to speak of it being oxidized. If it were not for mixing with extremely hot metal from the central portions of the cupola when the tap-hole is opened and the metal converges from all parts of the crucible, bad results would be had. As it is, many cases of alternating hard and soft castings, which look sound and have blow-holes side by side, can be traced to this bad practice when other charging conditions are correct.

Therefore, it can be emphasized that with all its advantages the cupola melting process has some draw-backs, one of which is plainly shown by the tests with nickel-chromium here de-

scribed. Every attention must be given the details of charging and blast conditions, so that however melting proceeds it may give reasonably uniform results.

Discussion

E. J. LOWRY.—I have done quite extensive work in melting in a cupola, and the paper presented by Dr. Moldenke is extremely interesting to me. However, while I was reading his paper this morning for the first time, I failed to notice the size of the charges. In the work which I have carried on, the charges have varied from 900 to 2500 pounds. Now in the smaller charges, I have found that they mix easily, but in the larger charges I have run mixed cupolas where there has been no extra coke for subdivision, and I have found that the second charge will run into the first; but where there is a third, fourth, fifth and sixth charge, that is not the case. There is a graduation in the mixture, of course, as would be expected in any melting process because of the piling of charges one on the other, but I think that we would all agree that the melting would take place in the melting zone and that melting zone would vary in each different cupola. I believe also that the uniformity of the cupola with the scientific practice would also have to be ascertained. I think you could go to one foundry and find a cupola of one design, perhaps scientific or perhaps the pet of the foundryman himself, and then you could go to another foundry and find a design exactly different. For instance, in investigating cupolas throughout the country, I have seen the tuyeres extending from two inches above the sand bed to as high as 22 inches. Of course in the case where the two inches above the sand bed was found, they had a mixing ladle and the tap hole was always open, but in this case I think you will find that the maximum amount of mixing charges would be in the first three, and I do not think you would find in the first charge the analysis of maximum content of any one of the elements that might be found in the third or fourth charges. However, I am not acquainted with the Mayari pig iron, so I do not know.

We went further than the melting charges alone. We made on the last charge special tests; we took nickel chromium wire, and on that wire suspended test bars and allowed those to go down in the special charge in the last heat. I think in one of the heats that we ran, one of the experiments that we ran, we had some twenty-seven different specimens, and those were taken out at different stated times through the charge door. From that we were trying to obtain the oxidation and also the increase of sulphur in the cupola. We found that the oxidation and the accumulation or the acquisition, you might call it, of sulphur from the coke did not take place until you got in the range of the melting zone. In this case the tuyeres were about 12 inches above the sand bottom, and the melting zone, if you can define it, would perhaps be found 24 to 30 inches above the tuyeres. By these tests which were run in duplicate and also at five different times, we established fairly accurately the burning out of silicon and the accumulation of carbon and of sulphur, and also a straight line for phosphorus which was practically unaffected. I did not come here this morning to discuss the paper, so I have not my figures, otherwise I could be fairly definite and show you that in a cupola running three distinct mixes, for instance, the first ten charges would be a 1.60 silicon, and the charges following that would be five or six charges of about 0.65 silicon and then a 1.20 silicon on top of the 0.65, and on top of that we go back to the 1.30 silicon. I have pictures which would show you that it would be the two full ladles previous to the 0.65 iron which would be affected by that 0.65 iron. But now, when you come to the other end, it will take three to four full ladles before you run out of the affected metal. Of course this metal is useful, because as Dr. Moldenke says, you distribute it throughout different castings to which the metal could be applied.

Dr. Moldenke.—It would lead too far to reply to all the points you have brought up in this discussion. You ask about the size of the metal charges used? In all cases these were the amount of iron melted with a layer of coke four inches deep. In the smallest cupola used, probably 500 pounds, and about 2000 in the case of the cupola of largest diameter.

Unquestionably in these runs, much melting must have been done along the lining, and some distance up. Indeed, I have often seen light scrap melt along the edges of a charge a considerable distance above the melting zone when the burden of the cupola was allowed to run a little low. Hence, the advisability of mixing as carefully as possible in the charges themselves.

In this series of tests, the unusual elements nickel and chromium gave a far better means of comparison of results, on analysis, than the silicons, in view of the variation in this element in the scrap charged in usual practice.

E. J. LOWRY.—It is quite right when you say the iron around the outside of the cupola will mix, I believe you agree with me that that iron will melt, dependent on the analysis, that if you are running a hard iron mix, the hard iron will run down first.

Annealing Gray Cast Iron

By J. F. HARPER and R. S. MACPHERRAN, Milwaukee

The investigation discussed in this paper was conducted by the Allis-Chalmers Mfg. Co., in order to determine the correct time and temperature for annealing gray iron castings, as well as to determine the effect of annealing and quenching on the physical properties. Each set of test bars was cast from the same 3,000-pound ladle, five transverse bars, 1 x 2 x 26 inches, being cast in each flask. When breaking several bars at a given temperature, only one bar was taken from any one flask. This was done to average the casting conditions.

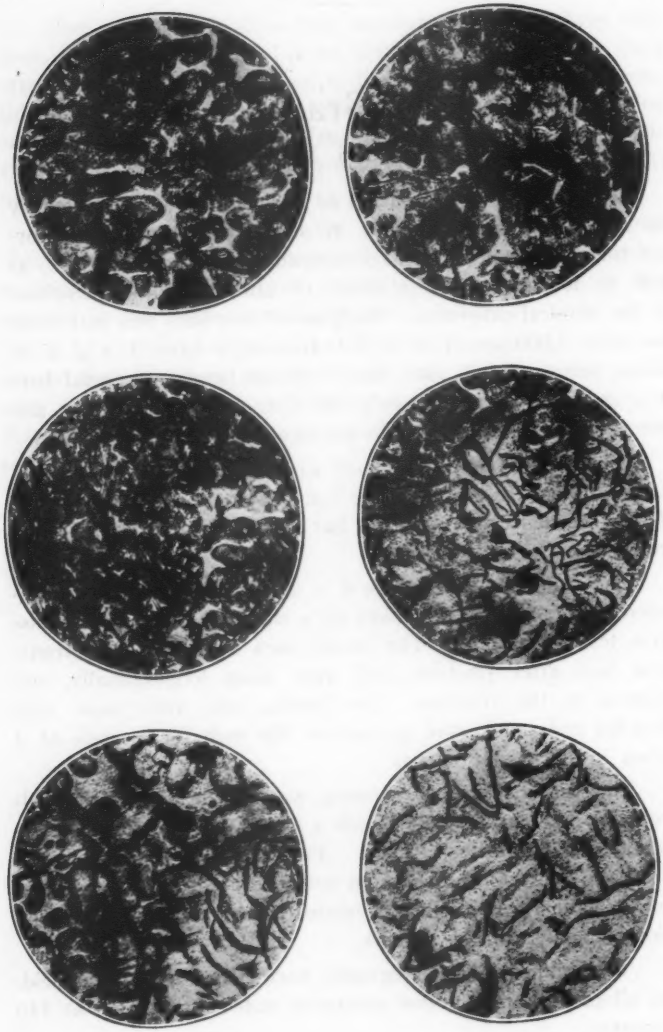
Brinell and scleroscope tests were made on a ground surface of transverse bars near the fracture or on a ground surface of the threaded end of the test bar when only tensile bars were broken.

The transverse bars were 1 x 2 inches and 24 inches between centers, and were broken on a standard Riehle-type transverse testing machine. The tensile bars were cut from transverse bars after fracture, and were taken longitudinally, and adjacent to the fracture. The tensile bars were made with threaded ends, and were ground to .564 inch for a space of 2 inches in the center of bar.

The furnace used for heating was of the semi-muffle oil-fired type and was equipped with a Leeds & Northrup-type potentiometer pyrometer system. For annealing purposes test bars were held at the maximum temperature for one hour, and cooled in the furnace. The combined carbon was determined by color and only used as a check.

All specimens for micrographs were etched with picric acid, and all micrographs, unless otherwise stated, are shown at 110 diameters.

The results of annealing for one hour on the first set of bars as shown in Fig. 5 would indicate that up to 1150 de-



A-7, as cast
K-7, 1150
G-1, 1300

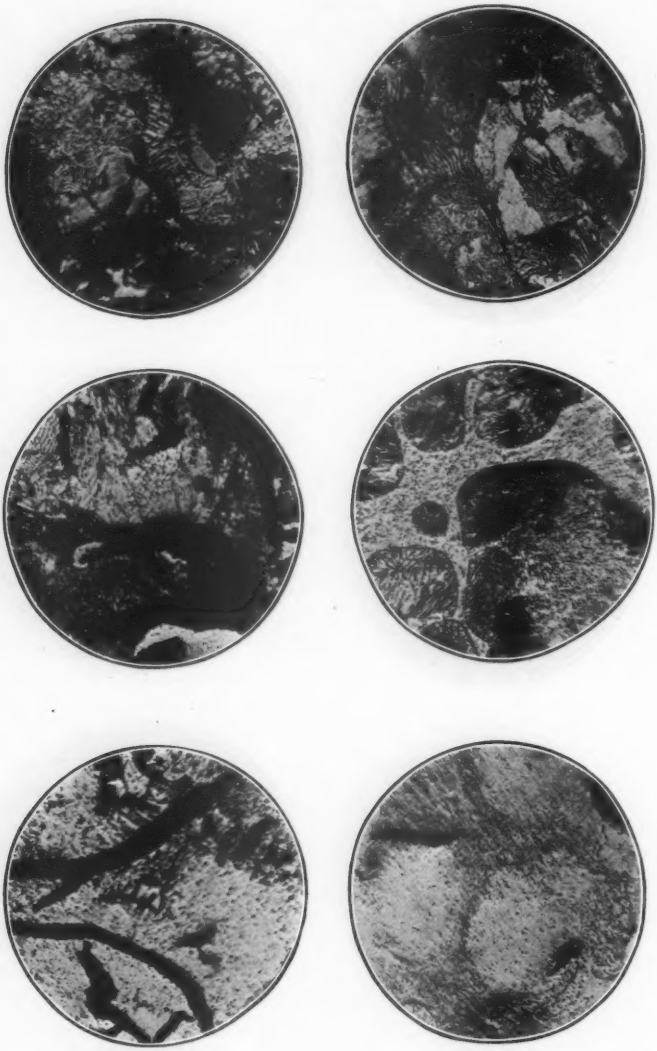
C-6, 800
K-2, 1250
H-5, 1400

FIG. 1

B-3, 500
H-8, 1200
K-4, 1300

G-1, 1150
I-10, 1250
L-5, 1400

FIG. 2



Bar 3, 500
H-8, 1200
K-4, 1300

G-1, 1150
J-10, 1250
L-5, 1400

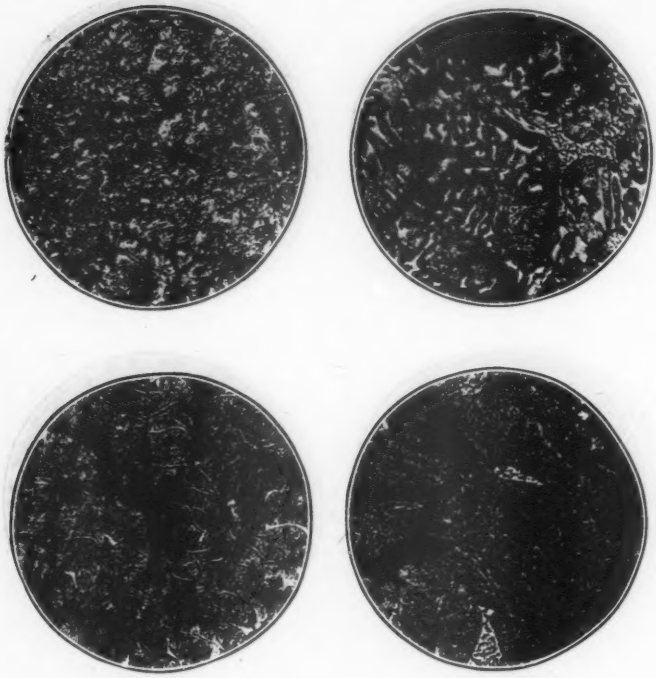
FIG. 3

B-5, 500
J-7, 1250

H-6, 1200
K-9, 1300

L-8, 1400

FIG. 4



M-8, 1500
A-6, 1600

M-8, 1500
A-6, 1600

FIG. 4 (*Continued*)

grees Fahr., there has been no loss of strength. Apparently there is a slight drop in the Scleroscope hardness, but no change in the Brinnel hardness until 1200 degrees Fahr. is passed. These results are confirmed by the change in combined carbon. Representative micrographs were taken from these bars as indicated by group letter, flask number and temperature of annealing, given under each micrograph. These are shown in Fig. 1.

It will be noted that no decided change had taken place until temperature of 1250 degrees Fahr. was reached. (Bar K-2). This change is progressive as temperature increases until at 1500 degrees Fahr. it is practically complete. There also

appeared to be a tendency of the graphite flakes to enlarge.

The results of annealing for a period of one hour as shown in Fig. 6 would indicate no loss of strength at 1150 degrees Fahr. nor material decrease in Brinell and Scleroscope hardness at this temperature.

At 1250 degrees Fahr. there is a slight drop in physical properties, as well as in hardness. These results are again confirmed by a decrease in combined carbon.

Representative micrographs were taken from these bars as above described, and are shown in Fig. 2. There will be noted a very slight change at 1200 degrees Fahr. followed by a decided change at 1300 degrees. This is again progressive, and at 1400 degrees is practically complete. These changes are shown in more detail in Fig. 3, where the same bars are shown at 400 diameter magnification.

In Figs. 7 and 8 the limited number of bars available permitted only a few tests to be made. These, however, were made

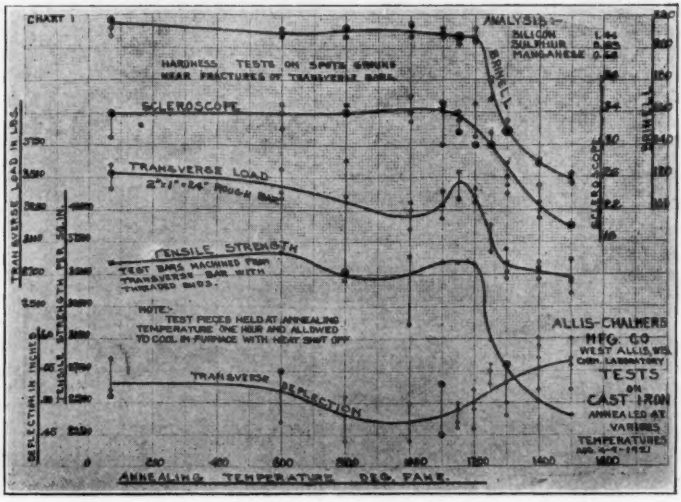


CHART 1
ANALYSIS
SILICON
SULPHUR
MANGANESE
HARDNESS TESTS ON SPOTS GROUND NEAR FRACTURES OF TRANSVERSE BARS
SCLEROSCOPE
BRINELL
TRANSVERSE LOAD
2"x1"-24" ROUGH BAR
TENSILE STRENGTH
TEST BARS MACHINED FROM TRANSVERSE BAR WITH THREADED ENDS.
NOTE:- TEST PIECES HELD AT ANNEALING TEMPERATURE ONE HOUR AND ALLOWED TO COOL IN FURNACE WITH HEAT SHUT OFF
TRANSVERSE DEFLECTION
ALLIS-CHALMERS MFG. CO. WEST ALLIS, WIS. CHEM. LABORATORY
TESTS ON CAST IRON ANNEALED AT VARIOUS TEMPERATURES
ANNEALING TEMPERATURE DEG. FAHR.

FIG. 5

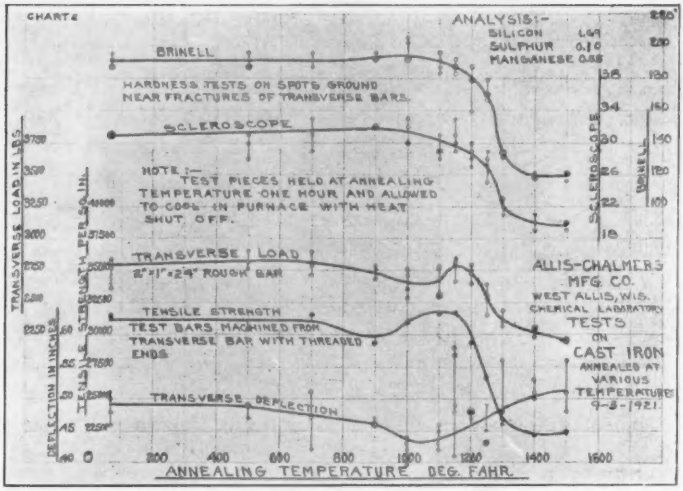


CHART 4
ANALYSIS:-
SILICON 1.69
SULPHUR 0.10
MANGANESE 0.55
BRINELL
HARDNESS TESTS ON SPOTS GROUND NEAR FRACTURES OF TRANSVERSE BARS.
SCLEROSCOPE
NOTE:-
TEST PIECES HELD AT ANNEALING TEMPERATURE ONE HOUR AND ALLOWED TO COOL IN FURNACE WITH HEAT SHUT OFF.
TRANSVERSE LOAD
2"x1"x24" ROUGH BAR
TENSILE STRENGTH
TEST BARS MACHINED FROM TRANSVERSE BAR WITH THREADED ENDS
TRANSVERSE DEFLECTION
ALLIS-CHALMERS MFG. CO.
WEST ALLIS, WIS.
CHEMICAL LABORATORY
TESTS ON CAST IRON ANNEALED AT VARIOUS TEMPERATURES
9-8-1921
TRANSVERSE LOAD IN LBS.
TENSILE STRENGTH PER SQ. IN.
DEFLECTION IN INCHES
SCLEROSCOPE
BRINELL
200 400 600 800 1000 1200 1400 1600
ANNEALING TEMPERATURE DEG. FAHR.

FIG. 6

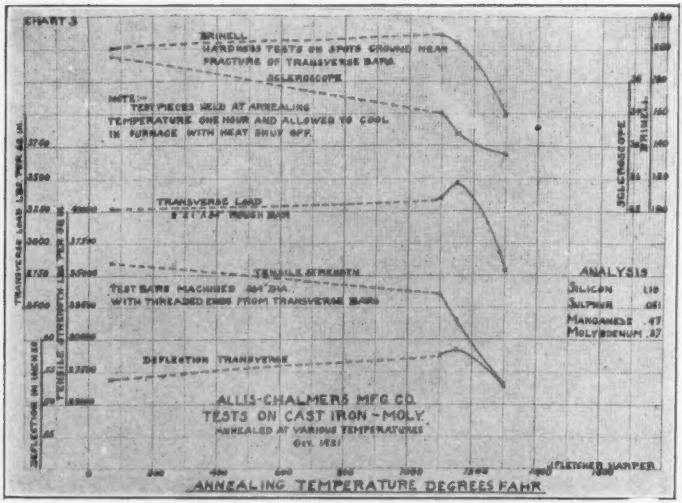


CHART 3
BRINELL
HARDNESS TESTS ON SPOTS GROUND NEAR FRACTURE OF TRANSVERSE BARS.
SCLEROSCOPE
NOTE:-
TEST PIECES HELD AT ANNEALING TEMPERATURE ONE HOUR AND ALLOWED TO COOL IN FURNACE WITH HEAT SHUT OFF.
TRANSVERSE LOAD
2"x1"x24" ROUGH BAR
TENSILE STRENGTH
TEST BARS MACHINED 564" DIA. WITH THREADED ENDS FROM TRANSVERSE BARS
DEFLECTION TRANSVERSE
ANALYSIS
SILICON 1.18
SULPHUR .081
MANGANESE .47
MOLYBDENUM .87
ALLIS-CHALMERS MFG. CO.
TESTS ON CAST IRON - MOLY.
ANNEALED AT VARIOUS TEMPERATURES
OCT. 1921
FLETCHER HARPER
ANNEALING TEMPERATURE DEGREES FAHR.

FIG. 7

at the important points, the results following closely those of Figs. 5 and 6.

To determine the element of length of time of annealing, the tests were made as shown in Fig. 9.

From Figs. 5, 6, 7 and 8 it would appear that the temperature of 1150 degrees Fahr. (for one hour) should not be exceeded when annealing to relieve machine or casting strains. In Fig. 9 is clearly shown the effect of continued annealing at this temperature. It will be noted that there is a material

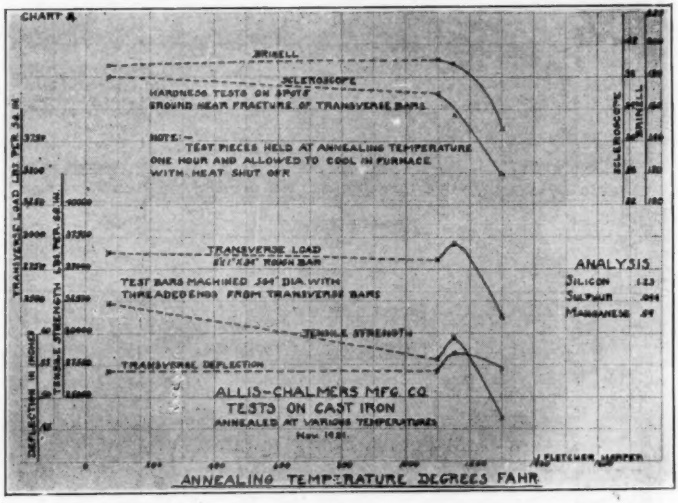


FIG. 8

loss of hardness and strength on the longer periods of time at this temperature.

Fig. 10 shows the effect of annealing at 1050 degrees Fahr. for various periods of time. This would indicate that this temperature of annealing for reasonable periods, does not tend to decrease materially the hardness or strength.

When annealing to increase machineability, only temperatures of from 1450 to 1550 degrees Fahr. will be found satisfactory. In this case, however, it should be noted the drop

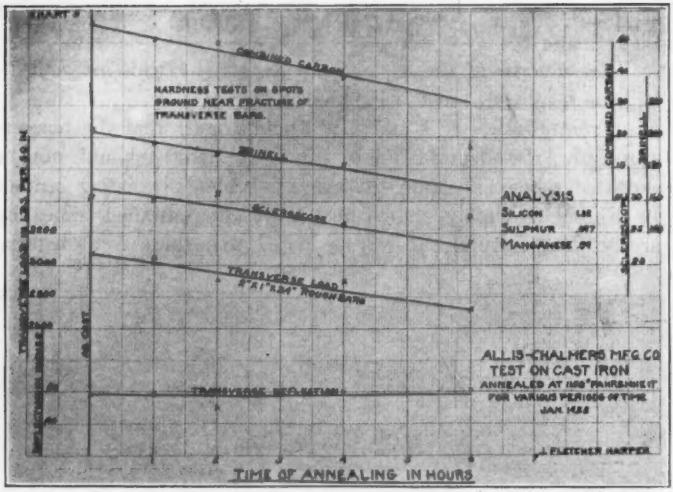


CHART 8
COMBINED CARBON
HARDNESS TESTS ON SPOTS GROUND NEAR FRACTURE OF TRANSVERSE BARS.
BRINELL
SCLEROSCOPE
TRANSVERSE LOAD 2"X1"X24" ROUGH BARS
TRANSVERSE DEFLECTION
AS CAST
ANALYSIS
SILICON 1.88
SULPHUR .097
MANGANESE .59
ALLIS-CHALMERS MFG. CO.
TEST ON CAST IRON
ANNEALED AT 1050° FAHRENHEIT FOR VARIOUS PERIODS OF TIME.
JAN. 1922
J. FLETCHER HARPER
TIME OF ANNEALING IN HOURS

FIG. 9

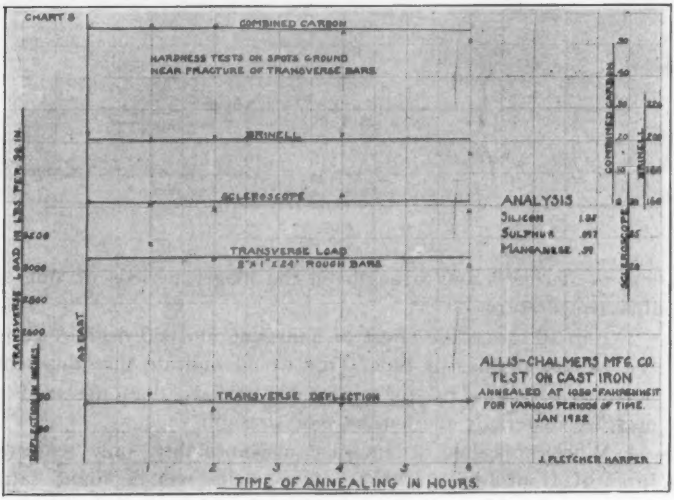


CHART 8
COMBINED CARBON
HARDNESS TESTS ON SPOTS GROUND NEAR FRACTURE OF TRANSVERSE BARS.
BRINELL
SCLEROSCOPE
TRANSVERSE LOAD 2"X1"X24" ROUGH BARS
TRANSVERSE DEFLECTION
AS CAST
ANALYSIS
SILICON 1.88
SULPHUR .097
MANGANESE .59
ALLIS-CHALMERS MFG. CO.
TEST ON CAST IRON
ANNEALED AT 1050° FAHRENHEIT FOR VARIOUS PERIODS OF TIME.
JAN. 1922
J. FLETCHER HARPER
TIME OF ANNEALING IN HOURS.

FIG. 10

in hardness is accompanied by a decided loss of strength.

The following experiments were made on the effect on cast iron of quenching at various temperatures.

In Fig. 11 the bars were held at the quenching temperature for one hour before quenching in water. It should be noted that above 1200 degrees Fahr. the Brinell hardness falls off until 1400 degrees Fahr. is reached, above which it rises very rapidly. The fall in Scleroscope hardness is less abrupt, but

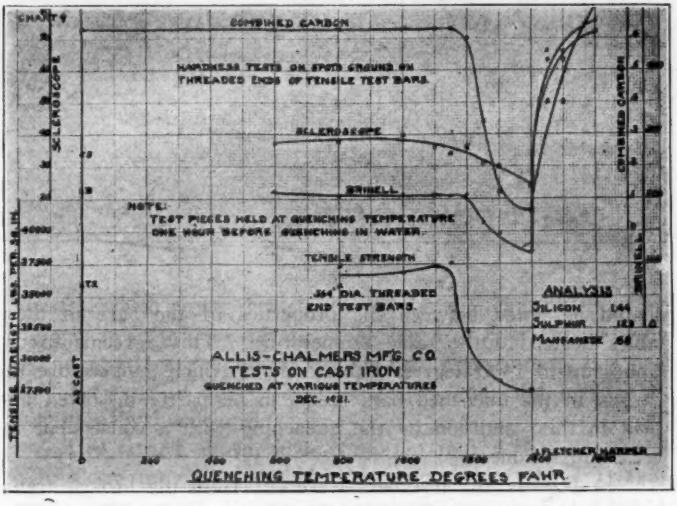


FIG. 11

both in decline and increase follows the Brinell test. The tensile strength falls off above 1150 degrees progressively until 1400 degrees is reached. When quenched above this temperature the bars were too hard to machine. The combined carbon begins to diminish at 1200 degrees which change continues progressively until over 1400 degrees, when it again rises rapidly.

The test bars here shown were cut from the broken transverse bars shown in Fig. 5 no bar being heated for these tests to a higher temperature than was given it in the tests.

In comparing results in Figs. 11 and 5, the close agreement

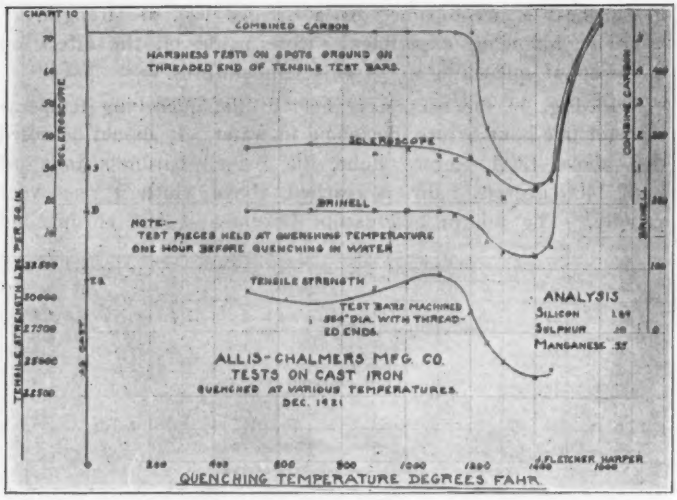


FIG. 12

should be noted between the properties of the bars in these tables heated to the same temperature. This agreement continues up to 1400 degrees Fahr. Above which temperature the carbon in the quenched bars seems to be partly dissolved and held in this condition by the quenching with a consequent increase in hardness.

In Fig. 12 the test bars were cut from the broken transverse bars shown in Fig. 6 and were quenched in water after holding at quenching temperature one hour.

It should be noted that above 1200 degrees Fahr. the Brinnel hardness falls off until 1400 degrees Fahr. is reached. Above which it increases rapidly. The change in Scleroscope hardness again follows the Brinnel test. The tensile strength begins to show a decrease at 1200 degrees which continues until 1400 degrees is reached. When quenched above this temperature the bars become unmachineable. The combined carbon seems to confirm the above tests.

In comparing results in Figs. 12 and 6 the agreement should again be noted between the properties of the bars in these

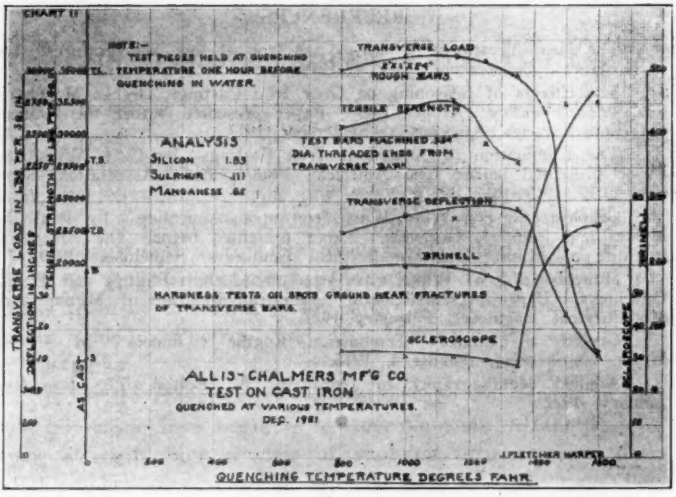


FIG. 13

charts, which were heated to the same temperature. This agreement continues up to 1400 degrees Fahr. above which as in Figs. 11 and 5, quenched bars become very hard, due probably to some of the carbon being dissolved, and held in this condition by quenching.

This is also shown in micrographs in Fig. 4. These show a breaking up of the carbides at temperatures above 1200 degrees Fahr. which change is practically complete at 1400 degrees Fahr. When quenched above this temperature the carbon is partly retained in solution with resulting increase in hardness. An interesting comparison is shown between micrographs in Figs. 2 and 3 and those of Fig. 4.

For Fig. 13 a set of bars was cast to check those in Figs. 11 and 12. The results agree extremely well. A continued drop in transverse strength above 1400 degrees Fahr. is due to the brittleness of the material.

From the results of these tests it would seem that until the temperature exceeds the critical the rate of cooling has no effect on the physical properties of cast iron.

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Discussion—Gray Cast Iron

CHAIRMAN A. O. BACKERT, *Past President*.—Mr. Cook, I think I voice the sentiment of all members of the American Foundrymen's association and of American foundrymen generally, in extending to you our very great appreciation and hearty thanks for having come over here and made this wonderful contribution to foundry practice. We have heard three papers on gray iron castings and perhaps it will be well to discuss them at this time. The papers by Mr. Cook, Messrs. Harper and MacPherron, and Dr. Moldenke are now open for discussion.

MR. R. F. HARRINGTON.—Sometime ago we decided to set aside all tensile bars breaking at approximately 40,000 pounds tensile strength, with a view of studying their chemical and metallographic properties in an endeavor to determine the cause of the high tensile strengths. We found excatly what Mr. Cook has found, namely, this network structure of the phosphide eutectic. After examining a great many specimens of about 40,000 tensile strength, we confirmed to a very great extent the fact that they invariably carry this network structure containing the phosphide eutectic in all physical properties discernible in the fractured piece. In the old days, in judging the fracture from a test plug from an under-fire furnace, if this network fracture appeared, it was felt that that would be a particularly high tensile strength iron; but the old timers thought that it was the combined carbon beginning to show.

MR. F. J. COOK.—In connection with Mr. MacPherron's discussion I would like to ask the writer what percentage of steel was used in the liner which he quotes.

MR. J. F. HARPER (who read Mr. MacPherron's discussion).—I haven't that available.

MR. F. J. COOK.—It was steel though?

MR. J. F. HARPER.—There was some steel.

MR. F. J. COOK.—I was only bringing out the point that in dealing with cast iron you have to limit it somewhere. If you begin to bring in steel you have to give a limit somewhere

and, of course, steel is outside the limit of this paper. He also referred to the high tensile strength bars that were difficult to machine. There is no difficulty whatever in machining the castings referred to.

I was interested in the remark that the wearing properties of the metal are not in accordance with the tensile strength, but indirectly as the hardness and closeness. I cannot agree with that at all, as far as English practice is concerned. We did extensive research work for two years on the wearing properties of cylinder iron, and the first idea we came to was that it was governed by hardness, but it was a very easy matter to show that that was not so under the conditions under which we tested. I have made specimens which were hard and gave good results and others which gave very bad results, that is, judging only by hardness. I have had castings that were normally soft but which gave good results in wearing properties, and from watching many thousands of tests, I am strongly of the opinion that the wearing qualities follow more closely the tensile strength of cast iron than any other property. The gentleman also referred to the large number of flywheels made and that only one or two failed. I can quote an equal or greater number of flywheels run at a rather higher peripheral speed—you state 100 feet per second, that is what we started from, and with many, many thousands of cases it is the boast of the firm I refer to that they have never had any trouble with flywheels even when they had engines that had governor troubles.

I did not quite make the statement attributed to me that American foundrymen grade only by silicon in the foundries; I said it appeared by technical papers that they grade only by silicon in the foundries.

DR. RICHARD MOLDENKE.—The round test bar is the right ideal. Our good friend, Mr. Cook, says that they cut the tensile specimens out of a square bar. I think the results vary a great deal more than when you cut them out of a round bar. It is going backward to do that, because you have entirely different metal on the edges than in the center. If you have a round bar, the metal is more uniform.

Mr. Cook states that it does not make any difference how much sulphur there is if the silicon balances up, but when it comes to the question of shock, high sulphur is very dangerous, though for tensile strength and transverse, it is all right.

MR. R. F. HARRINGTON.—It seems to me that Dr. Moldenke has hit the nail on the head in regard to this standard test bar. We do not even seem to be talking the same language on the question of test specimens.

MR. F. J. COOK.—I would like to say a few words in regard to Dr. Moldenke's valuable contribution, a great deal of which turns on the question of the size and shape of bars. I am absolutely in agreement with everything Dr. Moldenke says with regard to the difference in the different physical properties in the different parts of bars, and we in England are striving and have a committee formed to get out a specification for a bar that will be applicable to every country. It is very difficult at the present time, and it is impossible, as a matter of fact, to be able to gage the results obtained under very different conditions. For that purpose, being on this committee, I have studied the question of your arbitration bar, and I was absolutely astounded to find that I cannot find an arbitration bar. I was deeply interested to get hold of one, and in every foundry I have been in I have asked if they had an arbitration bar that I could see, but I have never seen one yet—that is, on this side. My reason for saying that is that you use a bar which is simply tested as cast. Now from a scientific point of view that is useless.

I have only had one arbitration bar submitted to me, and that was more than a couple of years before the war, and I was astounded that this bar instead of being 1¼ inch in diameter was nearer 1⅜ inch and was being tested on the deep side down, as shown by the marks of the shackle. I wrote back about this, and the reply was that it was made by an arbitration bar specification and therefore was an arbitration bar.

I know it is a difficult propostion to measure what is supposed to be a round bar, which may be oval or any other shape, and compare differences of strength due to differences in the

size of the bar. It is easily done with a square or oblong bar. We are anxious to get a common language for all countries, and we strive quite as hard as Americans who probably led the way in this respect. I am hoping that we shall eventually get a few gentlemen who are interested in the cast iron bar to get together and settle this question. Personally I favor the round bar although the argument may be used that the center is different from the side, even in the round bar, but we want to get the same language throughout, but I cannot see that that can be done unless you machine your round bars. With common castings, of course, the transverse bar cast in a square or oblong section gives you a very easy means of contact.

Another point was the Keep method of testing. I am quite aware of the many objections to the Keep test, but I have found with the particular class of iron I am dealing with, a very great advantage with the Keep method. However, the limits are very fine and you have to train yourself and be very familiar with the matter to think in very fine limits and to be able to diagnose the results you get with the ordinary cast iron. I agree with Dr. Moldenke that the Keep machine is of very little use, but in those particular strong irons, the question of shrinkage and deflection of your bar is a point which is very well worth watching.

Dr. Moldenke suggested that we might put in something with regard to cupola practice. I have done a great deal of work with regard to cupola practice and it is the essential point with regard to producing regularly high class iron. With regard to that one greatest point, which is the blast pressure, I intimated in the paper that is one of the things that has to be watched very closely. With the same given chemical analysis you all know you can get very different physical properties. You can even get in one sample brands of iron which come out with the same chemical analysis, but you can alter that difference within very wide limits by the application of blast pressure alone.

Mr. Elliott's paper is a very valuable contribution. He suggests that we are tied to a high sulphur and high phosphorus because of the quality of the iron available in our respective

countries, but that is not so. I can get as low sulphur and phosphorus as you can get in this or any other country, but I do not want it. I have used high sulphur for a great many years and was, in my own country, referred to as "having sulphur on the brain." The irons I referred to are not charcoal irons at all, they are irons produced in the ordinary way with coke and not charcoal.

H. P. KREULEN.—I would like to ask Mr. Cook regarding the boring of cylinders, whether it is necessary to form a high combined carbon and whether there would not be less lubrication there, less graphitic carbon combined with the oil? We know of some experiments that have been run that way. We found that taking the cylinder apart, that the bore was perfectly smooth, showing no graphite there to connect with the oil. Of course it may be that the chill was not very deep. I would like to know how to keep in that bore.

MR. F. J. COOK.—In regard to the chilling of bores, chilling is a misnomer, there is not chill, it is simply closing the grain; it should be denser. With regard to having lubrication of the cylinder, it does not affect it at all; we are willing to turn on high superheated steam without any lubrication at all. These engines are frequently used where the exhaust is used for back pressure, so we do not rely on the graphite for lubrication and have never known any trouble in regard to that. We have taken superheated steam without any lubrication of any description.

On the Desirability of Resuming Work on International Foundry Standards

By Walter Wood, Philadelphia, Pa.

The experiences of the world's industries during and since the great war have unquestionably served to emphasize the desirability of international co-operation in drawing up standards in foundry practice. This work was in a fair way of successful inauguration at the Congress called for St. Petersburg in 1914, by the International Association for Testing Materials, but was halted abruptly by the commencement of war. Since then, the industries of the world have learned much, and have found it possible to adjust themselves to conditions of practice formerly thought impossible. They have become fully alive to the advantages of agreement in practice and standards.

In view of the international character of this convention, it would seem appropriate to urge that the suspended work between countries as regards standardization of foundry practices, be taken up again along the lines of least resistance and looking toward eventual unanimity in the not too distant future. If it is not possible at this time to arrange for such a meeting as was held in Brussels in 1914, at which there were laid out proposed international standards for trading in pig iron by analysis, an international test bar, and international specifications for cast iron pipe; should it not be possible to get together those countries which are able and willing to start the work again, and let the others come in afterwards as they are in an economic position to do so?

The three standards above mentioned were originally picked out as possible of international standardization. The years that have passed have served to lessen the doubts as to the practicabilities involved instead of increasing them. The one stumbling block at the time, the objection of the British ironmaster to sell pig iron by analysis, has followed the fate

of the original similar objection of the American ironmaster, and today it is quite possible to buy British pig iron under guaranteed analysis. Why not then unite in an international standard in this regards, particularly as nearly all the other iron producing countries are already working along this line.

The test bar question is also ripe for concerted international study. It will take but few more tests to bring about a basis of agreement on an international bar, without interfering in the slightest with the testing practice of the individual countries concerned. Indeed, elaborate tests are being made in this country to find the properly dimensioned bar which will be equally sensitive to variations in load and deflection on transverse test. If the foundrymen of other countries will make similar researches upon mutually satisfactory basis of operation, international agreement will soon result.

It is, therefore, respectfully urged that this convention of the American Foundrymen's Association pass a resolution calling attention to the fact that it is now time to again take up the question of international foundry standards, and to request the visiting foundrymen of Europe to present the matter to their own foundry organizations with a view of early co-operation with us to this desired end.

Discussion

WALTER WOOD: Gentlemen, when the American Society for Testing Materials first took up its work, it was principally on the lines of steel. It had not gone on many years, only very few, before we brought up to the Association the question of cast iron. Of course in the years that have followed, the Association has taken up standards of all kinds, and to a very great, helpful use in the community. In connection with the American Society, the International Testing Association was also induced to take up the question of cast iron and also the specifications which it would be desirable to have developed. That question came up originally in the Budapest Conference about sixteen or eighteen years ago, and progressed from Con-

gress to Congress, the meetings being held, I think, at three year intervals, until they had resolutions and papers laid before the Council and prepared to go before a meeting in St. Petersburg. Then came the war. The paper I have here is more for the sake of putting upon record what I have stated to you so that all our members can gather by reading the transactions what we are now talking about and thus push forward the question of international specifications so that the whole world can work as a unit. Perhaps the commercial advantages of working as a unit so that the world's products, the buyer of the world's products, can always be assured of uniform deliveries, regardless of the country from which the material comes, I think is clear to us. The paper that has been prepared is on the desirability of resuming work on international foundry standards.

CHAIRMAN A. O. BACKERT: Gentlemen, Dr. Moldenke has a resolution.

Dr. Moldenke then presented the following resolution:

RESOLVED: That the American Foundrymen's Association will welcome the resumption of deliberations looking toward international agreement upon methods of foundry procedure and specification,

That the American Foundrymen's Association deems an early agreement on an international test bar, and the purchase and use of pig iron by its analysis only, essential in the interest of intensified export trade. The A. F. A. is prepared to co-operate with foundrymen's and engineering societies of other countries to this end.

F. J. COOK: I should like to say here, straight away, that as Vice Chairman of the British Cast Iron Research Association, and as one of the active members on a Committee on Test Bars for the British Foundrymen's Association, we shall welcome this question of co-operation between the different countries. We are very keen at the present time and we are working very hard; we have a very active committee formed, of which J. Shaw, a very live man, is at the head. He has been inundating me since I have been in this country with a pile, about so high, of communications on this particular point. He

does not know that the good time I am having will preclude my even looking at them, but we do want to get into strict co-operation with the American societies, and as this is a strictly international meeting, I think Dr. Moldenke's resolution is an exceptionally good one. I would like, however, to suggest that you rather limit the aims at the start. I mean to say that I think a great deal of the failure of the past has been by aiming at too many things. Perhaps failure is not quite the right word, but that they have not achieved what they could have done. I would like to see the question of the size of bars for cast iron dealt with in those international meetings. I may say here that the only difficulty we see with regard to round bars, which I would like to see adopted myself, is the question of the measurement and correlation of any deviation in size. I am speaking personally—we have not come to that decision as an Association—but I think there will be no difficulty whatever in adopting your inch and a quarter bar and in making it universal if the little difficulty of being able to differentiate the differences owing to difference of sizes can be easily gotten over, and I have no hesitation in assuring you of our hearty co-operation in this matter.

Raymond Gailly then gave the following translation of the discussion contributed by Marcel Remy:

M. REMY: The Belgian and French foundrymen have quite the spirit of co-operation with American and British foundrymen, and we can assure you that we will do all that we can to make the proposed meeting a success, but we must tell you that French and Belgian foundrymen do not like the tension test. Someone said some time ago that the American tensile machine did not pull straight, but in France and Belgian it is the same, and perhaps even in England, the tension machine does not pull straight either, and we find that that test does not give good results. M. Fremont, a French engineer, has made a very interesting study of a new kind of test, a shearing test, and as a result he has compared the results of those tests with the tension test and he has found that those tests are more accurate and give more accurate results than the tension test. When a test is taken, instead of taking a cast-

ing, a separate test, one box of metal is cast and the director takes a little piece of casting or punching or something like that, which is readily procured, and he can make a test with every piece. It is easy to have this test metal on the casting and it is better than a real tension bar, which does not prove the strength of the casting itself. You can have a bar that shows very good tensile strength and a casting taken out of the same ladle will show very poor tensile strength, or the contrary. I can assure you that the foundrymen in France and Belgium will take pleasure in doing everything possible to improve international relations between our lands and to co-operate with your association.

DR. MOLDENKE: May I just describe that Fremont test in a few minutes? That test is this: He takes a hollow drill and drills into a solid portion of the casting and a little round bar comes out, and then he planes that off to get it a quarter of an inch square, then he cuts it into quarter inch cubes and gets the measure of the strength of the iron in that way. That is the test as it is made, I believe.

CHAIRMAN A. O. BACKERT: Now gentlemen, the resolution offered by Dr. Moldenke is open for discussion and it is self-evident that we ought to have some action. If the resolution is adopted here, it will be referred to the board of directors for early attention. You have all heard the resolution. Are you ready for the question?

JOHN A. PENTON: What is the question?

DR. MOLDENKE: Read the resolution.

JOHN A. PENTON: I heard a small portion of that resolution as originally read, and it occurred to me that it contained some elements of a very desirable character that we ought not to let go by without saying a word or two, and ought not to pass the resolution without some further recognition. From my own little knowledge on the subject and what information I have, both here and in Europe bearing on the question of more close international relations on almost every subject in which all these various countries are interested—I think the resolu-

tion is very desirable and ought not to be passed in just a perfunctory way, but with some little enthusiasm. This country is growing more and more into an export country. Up to this time, the export of the iron and steel manufactured products to a great many countries in the world, the leadership of that export business, has rather gone to Great Britain. They have command of a great many of the markets of the world in a great many respects. Our own machine tool business ought to be a large business. I mention machine tools because they utilize a great deal of cast iron and will probably remain a large business. American machine tools, both before and since the war and during the war are being used in large quantity in Europe. It is a mixed question of international test bars, just like the metric system, but there ought to be some common ground on which we can stand and we ought to be working gradually toward that. It will be helpful in a great many directions, even if we do not arrive finally at some entirely common conclusion in which we can all co-operate. I notice in Mr. Cook's paper, there is quite a difference between the character of the test bars in England and those used in the United States. They have been using test bars over there and making them in a way that meets their own requirements, perhaps, and we have followed out certain studies which have given us certain ideas as to what are the most suitable bars for American practice. I think that for these two countries, the discussion of this subject and the improving of our universal methods will be a very good thing, especially in view of the volume of their business, as well as other European countries, like France, and Belgium, which are also large manufacturers, and perhaps for Germany too, which may, in the no distant future, become an important factor. They discussed these questions quite a good deal at the British Iron and Steel institute, the largest iron and steel institute of all Europe, as the other countries are all members of it and take a good part in the proceedings. Therefore, I believe it will work for the good of all, both here and abroad, if the suggestion that comes from Dr. Moldenke, inspired no doubt by the wonderful papers which our guests from Europe have prepared with some care and brought here, should be

unanimously carried, and a great deal of good will be a small part of our appreciation of the efforts made by these gentlemen and their courtesy in coming here.

CHAIRMAN A. O. BACKERT: We thank you, Mr. Penton, for calling attention to the importance of this resolution. Is there any further discussion?

Dr. Moldenke's resolution was then unanimously adopted.

A Study of the Weight of Iron Castings

By JOHN D. WISE, Urbana, Ill.

In recent years many phases of the art of shaping metals have been the subject of intensive research work. The art of shaping metals by the action of cutting tools is comparatively well developed, and the machine shop man possesses accurate data upon the majority of his important problems. But in the foundry, where metals are changed in shape by other methods, there has been comparatively little research work, although there are many important questions which can be solved only by scientific investigation. Of the different questions involved in the shaping of metals by casting, the excess weight is one of the largest problems and one that is of major importance to several large groups of people.

On first thought it might appear that all castings made in the same manner from the same pattern must necessarily be of the same weight, but observation of the weights of various castings made from the same pattern under identical conditions has disclosed surprising variations. Before taking up the causes and amount of variations it might be profitable to consider the groups to which such information will be of interest.

Purchaser Is Concerned

First, there is the user of the castings,—the man who pays, not only for the necessary, minimum weight, but also for all of the excess, useless weight. The purchaser of castings makes a peculiar concession to the foundryman. In his dealings with all other persons from whom he buys, he is guided by the principle that he must know in advance the amount of the invoice which will be rendered. For instance, when he orders steel or bolts, he is able to calculate to a nicety the amount he will have to pay for them. But to the foundryman he gives a more or less blanket order for a number of cast-

ings the weights of which generally do not correspond with those of previous shipments. The purchaser of castings realizes that the casting of minimum weight which he accepts serves its purpose as well or better than those of greater weight. Any excess weight is an extra expense to him. Therefore the user should be greatly interested in any study which will work toward the goal of standardization of the weights of castings.

The machine shop management is interested in castings weights. Frequently the machine shop purchases the casting and in this way has the direct interest in excess weight referred to above. Three other considerations enter into its problem in dealing with the overweight casting. First and most important is the removal of the surplus metal which is present on the surfaces to be finished. This frequently assumes dangerous proportions. For instance, it is not uncommon to find ¾ inch of stock where ¼ inch would be sufficient to eliminate the skin of the metal and to escape minor surface defects. The relative amount of metal occurring on finish pads and on portions where machining is not necessary will be covered later.

Handling Problem Is Affected

The second concern of the machine shop is the handling of overweight castings. In most cases the addition of 10 per cent to the weight of a given casting will not change it from a hand lifted weight to a crane-requiring weight or from one crane to another of larger capacity, but this will happen in a certain per cent of the cases and is, of course, an avoidable loss. The human factor enters here also since the work of handling castings by hand is materially lessened when the weight of the castings handled is decreased an average of 5 to 10 per cent. Of course such a decrease in weight reduces fatigue and increases efficiency.

The third concern of the machine shop in connection with overweight castings is in the use of jigs or fixtures. Since overweight takes the form of excess metal on the outside of the casting it follows that this excess metal interferes with jigs and fixtures, causing either a loss of time for

adjustment or rejection of the casting. The rapidly increasing use of jigs makes this factor one of prime importance.

Foundrymen constitute the last-mentioned, but certainly not the least-interested, group. They are, or should be, deeply interested in the standardization of weights of castings and in the reduction of standardized weight to a minimum. By decreasing the weight of all of the castings produced from one pattern to the minimum weight necessary to meet specifications, the foundryman will decrease the amount of money which he receives, since his invoice is rendered on a per pound basis. This result might appear to be to his disadvantage and cannot be explained away by assuming that the decreased amount of iron melted and handled will show a saving that will offset the loss of the revenue from the excess weight. The real solution for the foundryman consists in a moral interpretation of his duties toward his customers—a policy of rendering the maximum service for each dollar charged. He should constantly endeavor to keep the weight of the casting down to the minimum.

Ultimately the foundryman who seeks to build up his business on the principle of furnishing minimum weight castings will outdistance competitors who cannot render the same service. Also he will be able to meet the competition of the manufacturers of forgings and pressed steel parts, both of whom may be able to replace a casting by a member of less weight and greater uniformity and frequently at a less cost per piece. This competition presents a definite challenge to the foundry industry to meet the quality as well as the price of these products. Surely any steps leading to the standardization and reduction of casting weights are in the right direction when considering the broadest interests of the foundry industry.

Fig. 1 presents the result of a comparison of the weights of castings made from the same pattern or from patterns slightly altered to reduce the weight, maintaining in every case, however, the same requirements for the finished castings. Each horizontal line contains a record of the castings made from one pattern when hand molded and later when machine molded.

① Casting Number	② Casting Name	③ Weight when hand molded	④ Weight when mach. molded	⑤ Reduction-% ③−④ / ③×100	⑥ Saving per cste in lbs ③−④	⑦ No Rqd.	⑧ Rate per lb ¢	⑨ Total $ Saved ⑥×⑦×⑧
C-5R	Truck	38.6	33.3	13.7	5.3	220	6½	75.79
D-6	Base	340	312	8.2	28	15	6½	27.30
C-42A	Draw cyl cover	49.6	45	9.3	4.6	10	6½	2.87
B-74	Sand guard	24	23	4.1	1	20	6½	1.25
C-77	Squaring shaft	65.	58.	10.7	7	10	9	6.30
D-78	Frame	340	300	11.7	40	10	9	36.00
D-79A	Leveling table	121	112.	7.4	9.	10	9	8.10
D-80A	Base	264	200	24.2	64.	35	6½	145.60
C-201A	R.O.Bracket	50	38.	24	12.	5	9	5.40
C-202A	" "	58	38.	34.5	20	5	9	9.00
C-227	Sand guard cover	123.	110	10.6	13.	1	6½	.81
B-308	Safety st collar	2.5	1.85	30	.65	45	6½	1.90
B-310	Insp. hole cover.	6.2	5.5	11.3	.7	10	6½	.44
B-430	Leveling levers	4.3	4.	7.	.3	30	9	.81
B-431	" "	5.3	3.3	37.7	2.	30	9	5.40
B-549	Cylinder head	79.	60	24	19.	15	6½	17.81
A-1500	Muffler section	3.4	3.	11.7	.4	100	7	2.80
C-1500	" "	3.6	3.2	11.1	.4	150	7	4.20
C-2541	Wheel	38.	37.4	1.5	.6	100	6½	3.90
A-2599	Base	324	311.	4	13.	10	9	11.70
B-2638	Crank hub	4.1	4.1	0	0			
C-2651	" disc	12.4	9.6	22.6	2.8	20	9	5.04
C-2768	Bracket	2	1.3	35.	.7	40	9	2.52
B-3360	Cylinder head	55	54.8	.36	.2	10	6½	.12
A-5018	Jolt table	268	249	7.1	19	10	6½	12.35
A-5732	Draw piston	116	113.	2.6	3.	1	6½	.19
A-5872	Base top cover	12.	11	8.3	1	20	6½	1.30
A-7591	Muffler	2	1.8	10	.2	40	7	.56
A-7745	Car frame	71	56.	21.2	15.	20	6½	19.50
B-7745	" "	66	54.	18.2	12.	20	6½	15.60
A-7864	Base	282.	225	20.2	57	60	6½	222.30
A-7879	Shield	33.	29	12.1	4.	60	6½	15.60
A-7883	Wheel	27.2	24.3	10.6	2.9	500	6½	94.25
A-7982	Pressure hd. stop	12.3	12.	2.4	.3	35	6½	.68
A-8331	R.O.Trunion	66	64.	3	2.	20	6½	2.50
B-8331	" "	68.8	63.3	8.	5.5	20	6½	6.87
A-8405	Jolt piston	527.	475.	9.9	52.	10	6½	32.50
A-8415	Housing bushing	248	246.	.8	2	10	6½	1.25
A-8792	Jolt piston	330	316.	4.2	14	15	6½	13.12
D-8929	Leveling car	516.	480	6.6	36.	15	6½	33.75
C-8931	Draw cylinder	722.	535	26.	187.	15	6½	175.31
C-8934	Housing bushing	422.	415	1.6	7.	15	6½	6.56
TOTALS		5802.3	5137.75		664.55	1787		
AVERAGES		138.1	122.3	10.8	15.8	425		
TOTAL SAVING								$1029.25

FIG. 1—TABLE SHOWING COMPARISON OF WEIGHTS OF CASTINGS

The weights given in columns 3 and 4 are average weights of a number of castings. Column 5 shows the weight reduction in per cent; columns 6, 7, 8 and 9 show the weight reduction in pounds per casting, the number required, the price per pound, and lastly, the value of the saving for the quantity considered. The average weight reduction of 10.8 per cent indicates that a study of the reasons for the saving will produce important results since the saving is large enough to be of considerable importance. In considering the problem of weight reduction it will be convenient to set forth the successive steps in the making of a mold, assuming ordinary side floor work of moderate size. Beginning with the blueprint the steps in the making of a casting are as follows:

1. Decide on the amount of finish metal to be allowed.
2. Decide on method of molding.
3. Decide on the amount of draft.
4. Make the pattern.
5. Ram the mold.
6. Rap the pattern.
7. Draw the pattern.
8. Slick the mold.
9. Patch the mold.
10. Close and pour.

Patternmaker Determines Allowances

It will be noticed that the first three of the most important steps leading to the producing of a casting from a blueprint are performed in the pattern shop before the pattern is made. In too many cases the patternmaker decides these important factors without conferring with the foundry and machine departments. In so doing he influences to a large degree the subsequent methods these departments must employ and to a large degree the amount of unnecessary work to which they may be subjected. Obviously a more logical plan should be adopted at the start and carried throughout all the operations occurring between the blueprint and the finished casting. No single opera-

tion should be considered as a separate unit but each should be considered as a part of one logical plan.

The first factor, *deciding upon the amount of finish metal necessary,* is usually settled by the patternmaker in accordance with the following general rule: "It is always possible to machine off surplus metal while none can be added." He thus adds a "safe" amount of metal in order to allow for the unpredictable "come and go" of the casting. If it were known that the castings would be uniform in size it then would be possible to allow only enough finish metal to require the removal of the skin and its attendant surface imperfections. But all foundrymen are familiar with the fact that hand molding cannot produce this uniformity. Happily, most of them are also aware of the fact that machine molded castings possess uniformity of size and weight. It is a matter of general experience in the automotive and other industries that machine molding produces castings of uniform size and without excess metal for the machine shop to remove.

The second factor, *deciding upon the method of molding,* consists chiefly in the location of the parting line which seriously affects the production of the casting, but does not usually exert any effect on the weight.

Evils of Unnecessary Draft

The third factor, *deciding upon the amount of draft necessary,* affects the weight to a large degree. Again the patternmaker generally decides this question without conferring with the foundryman who must use the pattern. He works on the principle that "too much draft will not harm the pattern while too little will cause excessive breaking of the mold and will cause the pattern to be returned for alterations." He therefore allows liberal draft, a part of which is necessary and a part of which is superfluous. This excessive draft adds a constant and unnecessary weight of metal to the finished casting. Draft is necessary primarily in hand molding since it is impossible to draw the pattern straight upward from the sand by hand. Theoretically a pattern drawn vertically need have no

draft. This action is closely approximated by molding machines which are much more accurate than a human hand can be.

The fourth factor, ***making the pattern,*** has far reaching and interesting effects upon many other problems having to do with the cost of the casting but not on the item of weight. When the pattern is received in the foundry, the first operation performed is the *ramming the sand around it.* This introduces variable elements which greatly affect the weight. The ideal condition desired in ramming is that the sand shall be of the maximum density and yet allow proper venting; and second, that it shall be of exactly uniform density over the entire surface of the pattern. The skilled molder approaches, only in a rough way, the ideal condition. He obviously cannot produce a mold of exactly even density and the result invariably follows that the equal liquid pressure of the mold forces back the sand at the soft portions and produces at these points swells on the casting, all of which are unnecessary and add preventable weight. It also is true that the maximum density of sand is never obtained, for the molder leaves a large margin of safety to be certain of avoiding trouble due to lack of venting in the sand. Obviously this factor cannot be entirely eliminated but it can be reduced to a negligible quantity. The molding machine, with its constant uniformity from the beginning to the end of the day and from day to day, can accomplish exact uniformity of the entire surface of the mold and can approach the maximum uniform density much more closely than can the molder attempting it by hand.

Excessive Rapping Is Inexcusable

The sixth factor, ***rapping the pattern,*** is an operation introduced by the molder for the purpose of enlarging the mold in order that the pattern may be withdrawn with the least possible amount of damage to the sand. Rapping accomplishes this purpose but it also enlarges the cavity so that overweight is introduced into the casting. When considering the weight of the casting with a view of reducing it to a minimum, it is readily apparent that if rapping is eliminated entirely the reduction in weight sought for will be obtained. By omitting

rapping, however, the molder would invariably make matters worse by introducing excessive patching of the mold. Therefore he is forced to choose rapping as the lesser of the two evils. Again, the molding machine is suitable for accomplishing that which is impossible to the molder working by hand. It will draw the pattern vertically upward from the mold, loosening it from the clinging action of the sand by means of air or electrically operated vibrator which does not appreciably enlarge the cavity. In this way the rapping of the pattern can be eliminated with a resultant saving in weight.

The eighth and ninth factors, *slicking* and *patching the mold,* are in reality repair operations to overcome the damage done to the mold by the withdrawal of the pattern. Both of these operations should be eliminated but this is not possible when the pattern is drawn by hand. Molding machines draw the pattern so accurately that no slicking and patching are necessary.

The tenth factor, *closing and pouring the mold,* introduces little or no variation in the weight, unless the density of the iron is affected slightly by the height of pouring head or by such special methods as the rotation of molds, while being poured.

By dividing the 10 operations given on page 7 into two groups, first, those performed in the pattern shop, and second, those performed in the foundry, it is apparent that the problem is a common one for the foundry, machine shop, and the pattern shop to solve before work on the pattern is started. If each of these departments is to perform its particular portion of the work in the least time and at minimum cost the operation must be planned jointly from beginning to end by those who are responsible for its execution.

Variable and Constant Factors

In order to more intelligently attack the general problems of casting overweight the operations causing it may be divided into two classes; First, those causing variable amounts of overweight, and second, those causing constant amounts of overweight.

The operations causing variable excess weight are as follows:

1. Nonuniform ramming of the mold.
2. Rapping of the pattern.
3. Drawing of the pattern obliquely.
4. Slicking and patching the mold.

The operations causing constant excess weight are as follows:

1. Too much finish metal.
2. Too much draft.

It now becomes important that we be able to know definitely which of these factors adds the most excess weight to the casting so that we may know their relative importance and treat them accordingly.

No comprehensive study has been made of the importance of these different operations and therefore no answer can be definitely given here. However, it might be well to indicate some of the factors which will assign to these different operations their positions of relative importance. Excessive finish allowance metal exists on the parts which are to be machined and consequently, on a casting which is to be machined all over, this extra metal may take the shape of an extra ¼ inch, more or less, added to the entire surface of the casting. Its percentage to the total weight varies with the shape of the casting. It would be minimum on a spherical casting and maximum on a thin, flat casting of large area, such as a piano plate, and reach the maximum on a casting which is machined all over. Excess metal allowed for finish may be the most important factor in overweight or it may be one of the smallest considerations, depending entirely upon the shape of the casting.

Excessive draft is similarly variable. It is not necessary to use any draft on a spherical pattern parted on the diameter and it follows that such a casting would not carry any extra metal on account of draft. A cubical block would necessarily have draft on four of its six sides and the excess metal in such a case would be relatively heavy. A casting which is

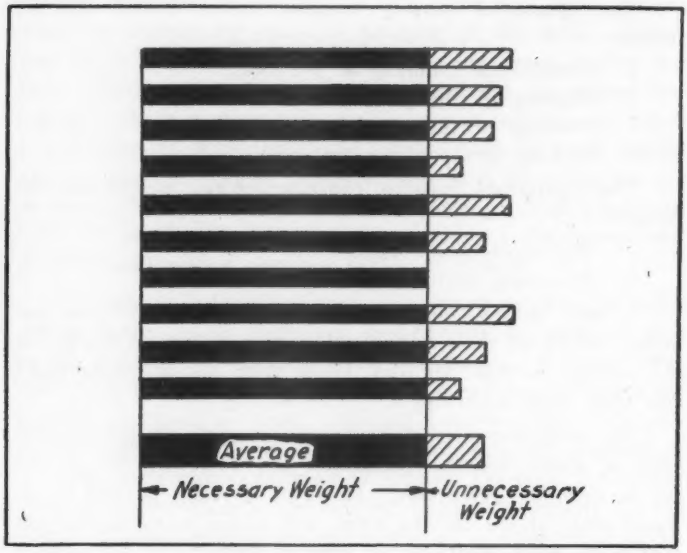


FIG. 2—TYPICAL CONDITION EXISTING IN THE CASE OF CASTINGS MADE FROM ONE PATTERN BY HAND MOLDING

deep in proportion to its area will have on it a maximum of excess metal due to draft allowance.

How Swells on Castings Are Caused

Swells on the castings are of two kinds. The first is an enlarging of the entire casting which is caused by the giving of the sand as the liquid pressure of the metal is exerted upon it. This is uniform over the entire surface and in amount is inversely in proportion to the density of the sand. The second class of swells are those which are confined to a small portion of the casting surface caused by light ramming at that particular point. These may be so slight as to be almost imperceptible in the case of an experienced molder and may assume such proportions as to be highly objectionable in the case of unskilled men. However, as previously mentioned, both are entirely eliminated in machine molding.

Rapping the pattern is usually performed backward and

forward and from right to left but seldom by driving the pattern into the sand. The casting is enlarged, therefore, rather uniformly on the sides but little, if any, on the top and bottom. The amount of enlargement depends upon the amount of rapping and this is determined by several things. A pattern of a shape difficult to draw is usually rapped more than one of easy drawing shape and an inexperienced molder finds it necessary to rap more strongly than the experienced molder. The use of air or electrically operated vibrators eliminates excess weight due to rapping.

The slicking process enlarges the mold uniformly, or approximately so, over the entire surface and affects different shapes of castings in the same manner that excess metal for finishing purposes affects them, as previously discussed. The principal point to bear in mind in regard to slicking is that it is an entirely preventable evil, since by eliminating rapping and

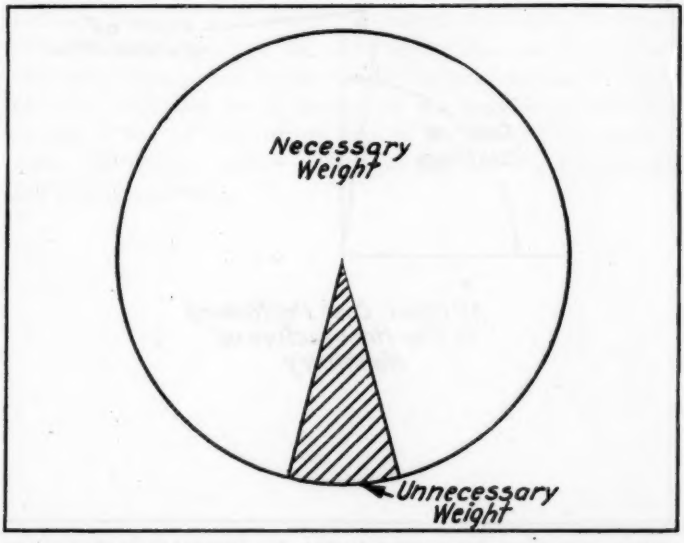


FIG. 3—THE AVERAGE 10.8 PER CENT REDUCTION OF WEIGHT SHOWN IN FIG. 1 IS REPRESENTED HERE GRAPHICALLY

by drawing the pattern accurately it is not necessary. Patching is in much the same class as slicking, except that it is usually local in effect. When building up a broken portion of the mold the molder naturally puts extra metal on the casting rather than not leaving enough.

Fig. 1 presents the data gathered when 42 light machinery patterns were changed from hand to machine molding. Fig. 2 shows the typical condition existing in the case of the castings made from one pattern when hand molded. The outstanding feature is the erratic variation. For the 42 different cases considered in Fig. 1 the average reduction is 10.8 per cent in weight. This is shown graphically in Fig. 3. The effects of this reduction are far reaching. Castings are purchased by weight; therefore the cost of rough castings is decreased 10.8 per cent to the user.

Since the cost of castings is about 20 to 30 per cent of the

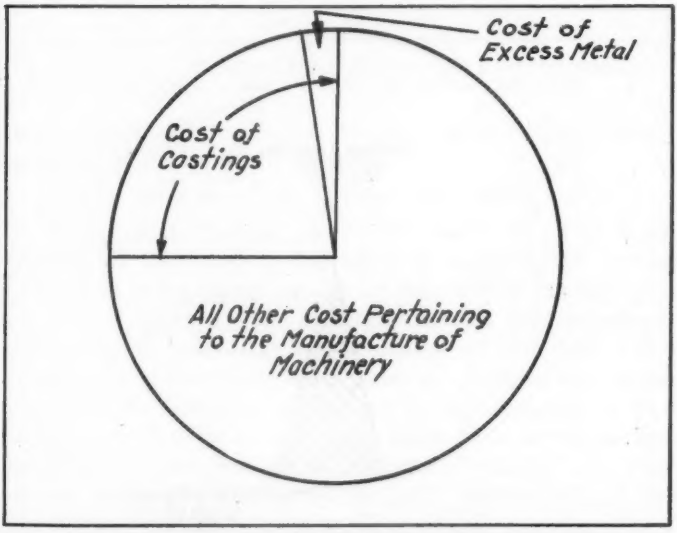


FIG. 4—THE COST OF EXCESS METAL TO THE MANUFACTURER OF MACHINERY IS SHOWN GRAPHICALLY

gross cost of light machinery this means a saving of 2 1/5 to 3 1/5 per cent which is added directly to the profit of the manufacturer, as indicated in Fig. 4.

Nor is this all. Following the casting into the machine shop we find there several items that will result in distinct savings.

1. There is less metal to be machined off.
2. There is less layout work.
3. Castings may be handled more rapidly in jigs.
4. There is less filing to be done on the rough surfaces.

No investigation has been made of the amount of saving effected by these changes in the machine shop but, whatever their magnitude, they decrease the cost of the finished casting and are a step in the right direction.

As far back as history records, castings have been made in essentially the manner that is employed today. At present there is evidence of a tendency for castings to be replaced by pressed steel parts. This tendency is bound to grow unless the foundry industry as a whole can reduce the cost of castings, not only rough castings, but also reduce the cost of finishing castings. Savings can be effected in the total number of hours of labor expended on a casting, in the amount of overhead burden borne by the casting and in the amount of material used. Moreover, a saving of 10.8 per cent in weight is possible and highly desirable.

Corrosion of Cast Iron

By H. Y. Carson, Birmingham, Ala.

The writer would respectfully memorialize the American Foundrymen's Association, on behalf of the study of the corrosion of cast iron. This subject is becoming increasingly important as the application of science to our every day existence is rapidly extended. The problems of water-supply, domestic heating, chemical manufacture and numerous other lines requiring cast iron in some form and subjecting it to unusually severe service conditions, have introduced questions of important financial and economic import, so that the foundry today is confronted with the fact that its product is not being used as extensively as it might.

This should not be, and it seems that the foundry might well be the first investigator of the causes of loss through corrosion, so that the consuming interests may not be forced to look about for remedies themselves. There are several groups of investigators preparing for this work at the moment, but the foundry as an organization seems not to be in evidence in this connection. The programmes so far presented deal principally with laboratory tests, which are very good in their way. Those rather familiar with cast iron, however, are doubtful as to the outcome of such lines of research as compared with actual service results extending over long periods of time. There are so many types of iron corrosion found in daily practice that imitation and reproduction in the laboratory is well nigh impossible.

It is most probable that the underground pipe corrosion tests now being conducted by the U. S. bureau of standards will bring forth many valuable data in time but a more detailed study of gray iron, malleable iron and cast steel might well parallel these investigations.

For these reasons foundrymen should be glad to co-operate with this research work, as it helps all to the common

good. It is therefore, urged that the American Foundrymen's Association authorize the executive board to create a committee on the corrosion of cast iron, to study the problems from the foundrymen's standpoint; as well as co-operate with any other bodies working on this subject.

APPENDIX

While there are actually perhaps hundreds of corrosion agents or corrosion stimulators found in nature, yet all of them may be grouped under two general heads:

A.—Oxidizing reagents, such as ordinary air nnd water, damp soil, moist gases mixed with air, etc.

B.—Hydrolizing reagents, such as strong dissolving acids, sulphur vapor mixed with steam, strong electric currents passed through the metal while it is submerged in an electrolyte, etc.

The effect of all oxidizing agents on iron is to produce rust, an oxide of iron. The effect of all hydrolizing agents on iron is to change the iron into some soluble salt, such as a chloride or sulphate, which can be dissolved in water. Hence a hydrolizing medium, or agent, can carry away all the iron and leave nothing behind but the insoluble portions of the iron, or shell. In the case of cast iron, the part that remains behind is the graphite and the silica from the silicides of iron originally present.

It is known that one of the effects of rusting, or oxidizing of iron, results in an increase in volume, this rust occupying several times the original volume of the iron from which it was formed. If rusted clear through, the increase in volume becomes very impressive. What is the amount of force produced during this swelling? This question has not yet been clearly or completely answered.

Apparatus has been devised by the U. S. bureau of standards at Washington for measuring the expansive force set up in reinforced concrete when electric currents are passed through the reinforcing steel, which currents thereby set up electrolysis and rusting of the steel. The following

statement on this swelling action of rust is contained on page 55 of technologic paper, No. 18 of the bureau of standards: " . . . experiments are sufficient to show that the force developed due to the corrosion of iron in concrete by electrolysis may reach a value of at least several thousand pounds per square inch, which is amply sufficient to produce the fractures observed in reinforced concrete blocks under the infiuence of electrolysis." It might well prove of further interest to study this effect with and without electric currents; also the effect of using different corrosion stimulators.

Rust itself is electro-negative to iron, and therefore may of itself be termed a stimulator, or reagent, to produce corrosion. When, however, rust engages itself into the pores or surface fissures of an iron which has sufficient strength to withstand the forces of the expanding rust, then the electro-chemical action stops, and this fully expanded rust now prevents the further entrance of oxygen. The rusting process stops there as has been repeatedly observed on cast iron and cast steel.

Suppose, however, that the crystals or grains of iron are not so bonded together that there is sufficient strength to mechanically withstand this swelling action in rusting. Electro-chemical action will then go on. The production of successive layers of rust increases the rate of corrosion, because the greater masses of oxide increasingly stimulate the galvanic action. Oxidation continues until all of the iron is changed to rust flakes.

To apply this mechanical theory of corrosion, one need but recall an every day observation known to practically everyone. The metals with highly deformed internal structure, which show cleavage planes and strain surfaces under the microscope—as in cold-rolled steel—rust in successive layers or flakes, and are rather rapidly destroyed when subjected to even ordinary corrosive reagents. The metals, however, which have an undeformed, interlocking grain structure— cast steel, cast iron, steel ingots, etc.—form an oxygen excluding coating of rust on their surfaces, and after a time either stop corroding, or at least have the cor-

roding action retarded greatly after the rust has expanded itself into the open parts of the metal.

Rust proceeds into the metal as far only as the bonding strength between the grains may equal the expanding force of the oxide. It may be and probably is a fact that a very weak open structure in cast metal will rust faster than a cast metal of dense, close-grain structure. Likewise cast steel which has its normal interlocking grain structure broken down by repeated passing through rolls loses its ability to resist the forces of rusting in some parallel proportion to the amount of working which it receives. It will, therefore, be of great practical interest to learn how much mechanical working steel will stand before it begins to succumb to this rapid oxidation. One example alone of the great benefit which might well result from such a study and from improved methods of casting would be the production of steel plate for ships, tanks, etc., that will withstand corrosion. This will prove a boon to mankind and should be the means of saving millions of dollars annually.

Among the problems worth immediate study, the following might be of interest:—

1. How much expansion force is produced when iron is changed to an oxide?

2. What differences in resistance to corrosive forces, if any, does the so-called "open-grained" and "close-grained" structure have in cast iron?

3. What is the comparative resistance to corrosion of cast steel, malleable cast iron and gray cast iron?

Discussion—Corrosion of Cast Iron

CHAIRMAN G. H. CLAMER.—Mr. Carson has just presented to you, as I understood from his paper, a definite recommendation that the study of cast iron be taken up by the A. F. A. I am a little doubtful as to whether an investigation of that kind would come within the province of this association, but for your information I believe I can outline to you the logical procedure whereby this very important subject might be given the attention which it deserves. The National Research Council has recently organized a committee on corrosion. That committee is organized to study the question of corrosion from a very fundamental standpoint, the theories underlying corrosion, etc. The American Society for Testing Materials has a committee on corrosion of steel. It has just recently organized a committee on the study of corrosion of non-ferrous alloys, starting with one or two definite problems, such as the corrosion of so-called acid resisting bronzes in mine water, the study of corrosion of condenser tubes—those two probably will be the first subjects considered. Committee A 5, I think it is, on the study of the corrosion of steel, has been in existence for a number of years, and has already presented some very valuable information upon the subject. Now it seems to me that the logical procedure would be to refer this matter possibly to the National Research Council or to the A. S. T. M. and that the A. F. A. be represented on that committee for the study of corrosion of cast iron. I think in that way the machinery could be put into the work in good order. So if a suggestion of that kind is agreeable to the members attending this meeting, I would appreciate it if someone would so move.

DR. R. MOLDENKE—I would like to say a few words on this subject. One of the difficulties with these boards—you speak about the National Research Council and the A. S. T. M.,—is that they do not always include foundrymen. I differ with you on the subject that this ought to be transferred somewhere else. I think the foundrymen are the men who want to have something to say about the product they make, cast iron, and I would rather see it this way: that our executive

board authorize the creation of a committee of foundrymen to work on this and that this committee take it up with the other societies to work hand in hand, so that the result will come. If, however, you have one foundryman and about fifteen engineers on a committee, it won't do.

I would like to make a motion that it is the sense of this meeting that the aims and purposes of this memorial be approved and that the matter be referred to our executive board for action. Then they can work it out and put it in form, or if they appoint a committee of three, or four, or five, with Mr. Carson as chairman, they will naturally work with us, but we need more actual foundrymen to work on this. As I say, on the other side of the water, there is a great struggle between the steel and cast iron pipe. We all know that cast iron is much better in resistance to corrosion than steel; therefore we would like to see more actual foundrymen working on this; therefore I move that it is the sense of the meeting that the memorial covers what is right and that it be referred to the executive board for suitable action.

CHAIRMAN G. H. CLAMER.—That is the real way to do it, to get it first before the board and the board appoint a committee of the A. F. A., and through that committee cooperate with these other bodies working on the same subject. The idea back of the whole thing is not to have any duplication of effort; in other words, to get the work going in parallel. You have heard the motion that this report be accepted and that the recommendations therein be approved and that the matter be referred to the board with the recommendation that a committee on the corrosion of cast iron be appointed.

The motion was seconded and carried.

MR. F. E. HALL.—I am interested in connection with one point raised by this paper, namely, on the relative corrosion of wrought iron, malleable iron, cast iron and steel. The company I am now with has been conducting some experiments on this subject over a period of ten years. So far as

we have gone, plotting the curves on the actual loss in weight of equal sized specimens immersed in still water, water such as that found in our lakes here, over a period of eight years, the plotting showed so little variation in the different metals that it was hardly worth considering. We found, however, that cast iron corroded more uniformly; the amount removed from the surface of the specimen was practically the same in weight, but it was removed uniformly over the entire surface; whereas steel and wrought iron were pitted locally by its action. The effect of the so-called non-corrosive irons which were sold under different trade names, appears to be entirely confined to the scale on the surface. The surface, being an oxide, protects the metal and as soon as it is broken, the corrosion takes place as rapidly as in any metal. One other point I might mention is an attempt to get some light on the controversy as to whether the corrosion was due to galvanic action or simply the oxidation effect of carbon dioxide. A piece of solid cast iron was brought into a flask of boiling water which had been boiled sufficiently long to exclude all air, and sealed when full of vapor, thus precluding the access of oxygen other than that contained in the water combined with the hydrogen in the water. This was allowed to remain for one month, and did not lose in any respect its power. On removing the stopper from the flask and allowing air to enter without agitating the water, inside half an hour a distinct film of rust formed, showing that whether you call it galvanic action or whatever you call it, it is necessary to have free oxygen transmitted by solution through the water to the metal to get corrosion when in contact with the water. In order to confirm this, a copper wire was wound around the piece and this was treated in the same way, except that a solution of salamoniac was used, which, as you all know, will start corrosion on steel almost instantly. At the end of ten days there was just a scarcely perceptible film of rust formed, although the galvanic action would naturally occur from the contact of the copper and the iron, showing it was necessary in any case to have the free oxygen present.

Report of the A. F. A. Committee on General Specifications for Cast Iron

Your Committee begs to report that it has worked jointly with Committee A-3, of the American Society for Testing Materials, and that considerable progress has been made. A set of specifications for "High Test" cast iron has been drawn up, and the existing specifications for foundry pig iron have been brought up to date. While your committee has signified its approval of this joint action, the committee vote of our sister society is not yet complete and the full text of the specification is, therefore, not yet available for action. However, the following are the salient features of these documents:—

Foundry Pig Iron

The changes made in the present form of the specifications are of minor character, and in the wording only. Suggested action which has not found favor in current practice of buying and selling pig iron has been left out, and the standard methods of sampling and analysis of the two societies has been made the basis of decision in cases of dispute.

High Test Cast Iron

This is a new set of specifications covering all classes of iron with high strength, as obtained usually by additions of steel to the cupola mixture. The general form of the specifications follows that of the existing set for gray iron castings, but the following differences may be noted. There is no division into light, medium and heavy work, with different values for each. The arbitration test bar under transverse test must sustain a load of 3800 pounds, with 0.12 inch deflection, before breaking; and if a tensile test is required, this should show 28,000 pounds per square inch.

In view of our inability to present the actual test of the above specifications to the Association at this time, though the critical figures have been given, it is respectfully recommended

that the Association authorize the Executive Board to receive the specifications when finally approved by the joint committee of both associations, and if found satisfactory, recommend them to the foundry industry as "tentative" until after at least a year's trial and discussion, they may be made "Standard."

Shatter Test for Foundry Coke

The rapidly extending use of by-product foundry coke has made it necessary to give special attention to the subject of its friability, and Committee D-6, of the A. S. T. M., has been devoting the past year to work along this line. As the result, there will be reported for discussion and eventual standardization, a method which should insure the delivery of coke to the foundryman fit to use in his cupola. The apparatus—to be used at the coke plant—will be fully described and also the method of taking the sample. Fifty pounds of the sample are placed in the machine and dropped four times on a plate, from the height of six feet. The material finally obtained is then screened to give the percentages of the coke remaining on a 2, 1½, 1 and ½-inch screen, and that passing through the last named one. From these figures there will be eventually drawn up a standard requirement, as experience will show, the present object being to standardize the method, so that the producers of coke may have brought to their immediate attention the condition of their coke as received by the foundryman, and take whatever measures may be possible to insure strong and uniform material.

The foundry world will await with much interest the outcome of this important improvement in the valuation of coke for melting purposes in the cupola.

Respectfully submitted,

GEO. K. ELLIOTT,
R. M. VON HOFEN,
S. C. WEEKS,
I. A. WYANT,
RICHARD MOLDENKE, *Chairman.*

Report of A. F. A. Sub-Committee on Specifications for Cast Iron Wheels

Your committee, which was appointed in 1916, prepared a set of specifications for cast iron car wheels and then was instructed to work with Sub-Committee IV of Committee A-3 of the American Society for Testing Materials, the object being that the A. F. A. specifications should agree with the A. S. T. M. specifications. The Chairman was appointed a member of this Committee.

After several meetings the American Society for Testing Materials adopted at its 1921 convention tentative specifications designated as A-46-21 T, which are published in full herewith. These specifications cover the same weights of 33-inch wheels as adopted for standards by the American Railway association.

It is, therefore, our request that these specifications be accepted by the American Foundrymen's Association as tentative specifications, and that after a year, unless some changes are proposed, they be adopted as standard.

H. W. UFER,
Chairman

Tentative Specifications for Cast-Iron Car Wheels

AMERICAN SOCIETY FOR TESTING MATERIALS

Serial Designation: A 46-21 T.

I. Material.

1. Wheels shall be made of a mixture of such composition that will produce the required chill in the tread and not show any mottled iron in the plates except around the chaplets where it shall not extend more than ½ in. (12.7 mm.)

II. CHEMICAL REQUIREMENTS.

2. (*a*) The wheels shall conform to the following requirements as to chemical composition:

Combined Carbon	0.50 - 0.85 per cent
Silicon	0.45 - 0.75 per cent
Manganese	0.50 - 0.75 per cent
Phosphorus	not over 0.40 per cent
Sulfur	" " 0.18 per cent

(*b*) The minimum percentage of manganese shall be not less than three times the sulfur content.

(*c*) It is desired that the phosphorus content shall not exceed 0.30 per cent.

3. Drillings for chemical analysis shall be taken from drill hole bored entirely through the back double plate of the wheel between core legs.

III. DIMENSIONS, WEIGHT AND DESIGN OF WHEELS

4. Patterns and chillers must be such that they will produce wheels according to dimensions shown on drawings furnished by the purchaser.

5. The normal circumference conforming to the specified diameter shall be measured at a point $1\frac{33}{32}$ in. (43.65 mm.) from the gaging point on the throat of the flange. Wheels shall not vary more than $\frac{7}{16}$ in. (11.11 mm.) above or below normal size, measured on the circumference, but only $\frac{5}{16}$ in. (7.94 mm.) variation above or below normal size shall be allowed for any day's cast from one cupola.

The thickness of the flange shall be regulated by a maximum and minimum flange thickness gage which shall not be more than $\frac{1}{16}$ in. (1.59 mm.) over nor more than $\frac{1}{16}$ in. (1.59 mm.) under the normal flange.

6. All wheels shall be taped with standard design of wheel circumference tape and have the numbers 1, 2, 3, 4, and 5 stamped ⅛ in. (3.18 mm.) apart, the figure "3" to represent normal tape size limited by $\frac{1}{16}$ in. (1.59 mm.) over or under the standard circumference, which for 33-in. (838.2-mm.) wheels will be 103.67 in. (2633.2 mm.). The fig-

ure "1" shall represent the smallest diameter, and the figure "5" the largest diameter. Tape sizes shall be stenciled in plain figures on the plate of the wheel or otherwise designated, as may be required by the purchaser.

7. (*a*) If wheels are ordered in accordance with A. R. A. standard drawings the weight shall be as follows:

Maximum Gross Weight of Car.			Normal Weight of Wheel.		Minimum Weight of Wheel.	
Lb.	Kg.		Lb.	Kg.	Lb.	Kg.
95 000	43 000	.....	650	295	640	290
132 000	59 750	.....	700	317	690	313
169 000	76 500	.....	750	340	740	335
210 000	95 250	.....	850	385	840	380

(*b*) In case of wheels ordered with cores smaller in diameter than the standard, the additional weight shall be considered as additional to the normal weight given in the above table and be paid for by the purchaser.

(c) In any shipment where the average weight of wheels is above the normal weight given in the above table the excess weight shall be at the expense of the manufacturer.

IV. INSPECTION.

8. Manufacturers shall notify the purchaser when ready to make shipment and shall furnish all necessary facilities and labor to enable the inspector to make test and prompt shipment of wheels.

9. The body of the wheel shall be free from slag, shrinkage, or blow holes. The tread and throat shall be free from irregular wrinkles, slag, sand wash, chill cracks or sweat. Wheels will not be rejected on account of cracks around the circumference of the center core commonly known as "drawn hubs" or slight shrinkage holes on the face of the hub which will not interfere with the proper mounting of the wheels.

10. All wheels shall be marked and numbered consecutively in accordance with instructions issued by the purchaser. All wheels shall have the initials of purchaser, wheel number, weight of wheel, month, day and year when made plainly cast on the inside plate of the wheel. No wheels shall have duplicate numbers and all indistinct or duplicate numbers may be corrected only after having received the approval of the inspector. All wheels shall have the name of manufacturer and place of manufacture cast on the outside plate of the wheel.

11. When ready for inspection the wheels shall be arranged in groups, all wheels of the same date being grouped together, and

for each 102 wheels which pass inspection and are ready for shipment, two representative wheels shall be taken, one of which shall be subjected to the thermal test and the other shall be used for the drop test.

12. (*a*) In making the thermal test the wheel shall be laid with the flange downward in the sand and channelway 1½ in. (38 mm.) wide and 4 in. (102 mm.) deep molded in green sand around the wheel, the tread of the wheel to form one side of the channelway and the clean flange forming as much of the bottom as its width will cover. This channelway shall be filled with molten cast iron which shall be hot enough when poured, so that the ring cast, when the metal is cold, will be solid and free from wrinkles. The time when pouring ceases shall be noted and after the time given in Table I has elapsed an examination of the wheel shall be made. If the wheel is broken in two or more pieces or any crack in the plate extends through the rim, all the wheels bearing the same tape size as represented by the sample shall be rejected.

TABLE I.

Weight of Wheel. Lb.	Kg.	Cooling Ttime, Minutes.	Weight of Wheel. Lb.	Kg.	Cooling Time, Minutes.
650	295	2	750	340	2½
700	317	2	850	385	3

(*b*) In order to prevent spitting while pouring, the tread and flange may be covered with a coat of shellac. Wheels selected for test which are wet or which have been exposed to snow or frost may be warmed sufficiently to dry them or remove the frost before testing, but under no circumstances shall the thermal test be applied to a wheel that in any part feels warm to the hand.

13. (*a*) The anvil of the drop testing machine shall be supported on rubble masonry or a concrete foundation at least 2 ft. (610 mm.) deep and shall weigh not less than 1700 lb. (770 kg.). The striking face of the tup shall be 9 in. (229 mm.) in diameter and flat. The face of each of the three bosses supporting the wheel under test shall be flat and measure 5 in. (127 mm.) in width.

(*b*) The test wheel shall be so placed on three supports with the flange down, that the tup will strike centrally on the hub. The test wheel shall pass the requirements given in Table II without breaking in two or more pieces. If the test wheel fails, all wheels bearing the same tape size shall be rejected.

Weight of Wheel, Lb.	Kg.	Weight of Tup,		Height of Drop. Ft.	Cm.	Number of Blows
650	295	200	90	9	275	12
700	317	200	90	10½	320	12
750	340	200	90	12	365	12
850	385	200	90	15	460	12

(*c*) If the test wheel cracks before the twelfth blow it shall be required to stand 15 blows before breaking in two or more pieces.

14. The wheel selected for drop test shall be broken so that the chill may be examined at least four different portions of the wheel. The depth of pure white iron shall conform to the following requirements:

Weight of Wheel.		Maximum Depth.				Minimum Depth.			
		At Middle of Tread.		At Throat.		At Middle, of Tread.		At Throat.	
Lb.	Kg.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.
650	295	1	25.4	7/8	22.2	1/2	12.7	3/8	09.5
700	317	1 1/16	27.	7/8	22.2	1/2	12,7	7/16	11.1
750	340	1 1/8	28.6	7/8	22.2	1/2	12.7	1/2	12.7
850	385	1 1/8	28.6	7/8	22.2	1/2	12.7	1/2	12.7

The depth of the chill shall not vary more than 1/4 in. (6.35 mm.) in the middle of the tread on the different portions measured. If the sample does not conform to the requirements stated, all wheels of the tape size represented by the sample shall be rejected.

V. RETEST.

15. Should the test wheel selected for the drop test, thermal test, or chill test fail to meet the requirements specified, all wheels bearing the same tape size shall be rejected (Sections 12, 13 and 14). The inspector shall then select another wheel of a different tape size, which shall be submitted to the same test as the wheel which failed and if it passes the requirements of the test the remainder of the lot shall be accepted, provided the requirements of all other tests have been met.

VI. REJECTION

16. The numbers of all wheels which have been rejected because of failure to meet the requirements of the drop test, thermal test, or chill test shall be noted and such wheels shall not be submitted for test at any future time.

17. Individual wheels shall be rejected if they are:

(*a*) Under the minimum weight specified;

(*b*) Have surface defects mentioned in Section 9;

(*c*) Over or under the specified dimensions.

Time Studies and Job Analysis in the Foundry

By A. J. KRAMER, Chicago

To representatives of the foundry fraternity, time study as a science really requires no introduction, no elementary explanation of its uses; and surely needs no vouching for its value in the industry. However, of this point I am certainly sure: That if you have not yet taken advantage of time study methods for arriving at improvements in equipment, price setting for piece work, task setting for bonus or premium payment, or to maintain low production costs, you are not utilizing a sure, legitimate and praiseworthy means for attainment of those features most essential to profitable manufacturing.

To say that it has not had abuses and that on account of these it has not been regarded highly enough by certain groups of workers, is beside the question. I shall therefore treat of the value of time study work, job analysis and specifications, as I have found them.

Setting Equitable Piece Work Prices

Observation has shown that a large portion of the total utilization of time studies consists in setting piece work prices equitable in the strictest possible sense of the word, fair to the employer, and just to the worker.

The foundry, as a field for the application of scientific management and time study work in particular, presents wonderful possibilities. While the work of the foundry is of such scope as to call for ability above the average in solving the problems of management, and unlimited ingenuity in the making of castings, much of the productive work is of a sufficiently repetitive nature to enable standards to be set so that the work of setting task times and piece work prices becomes more simplified and by the same token, more accurate.

There are many good reasons why time studies should be taken. Of these, the six most important are:

1. To set up standard times as a basis for proper piece work prices, equally as fair to the workman as to the employer, so that a man may earn a just day's wage for a just day's work.

2. To set piece work prices as nearly accurate as possible and avoid any question as to their correctness, or as to the soundness of the method used in their determination.

3. To increase the efficiency and earning power of the workman and consequently increase production through the elimination of fatiguing and unnecessary motions.

4. To establish equality and uniformity in prices for similar classes of work and for similar occupations, through standardizing working conditions and equipment.

5. To seek out ways and means of improving methods and equipment, thereby increasing production.

6. To relieve the foreman of a great deal of detail and worry over matters which should be extraneous to the executive functions. These constitute his chief responsibility and should therefore be his first duty.

As an illustration of the first reason, consider the shops where the time study method of setting prices is not used, and where piece work prices as a rule are estimated. It has been found in many cases that the personality of those who estimate prices is to some extent reflected in such estimated prices. Persons possessing a liberal turn of mind show tendencies toward generosity in their prices, and in like fashion, "tight" prices are the rule in departments where the persons who estimate prices are of a less liberal turn of mind.

Prices which are too high are unfair to the employer, and prices which are too low are equally as unfair to the workman. A correct price gives the workman a chance to earn a just day's wage and in so doing he is bound to give a just day's work in return. By being satisfied with his work and remaining in continuous employment, he helps to reduce the labor turnover, which at all times is a problem of importance.

An analysis of the second reason shows it to bear a certain relation to the first reason, in which we attack the method of setting prices by estimating. Those who have to do with the setting of piece work prices must always be in a position to

show reasons for their decisions and sometimes prove the correctness of the prices, especially in cases wherein the workman fails to earn the wages it is desired he should earn. In some factories, prices are estimated by foremen, and while the foreman no doubt is well qualified in this regard, the departmental morale suffers when he is placed on the defensive and made to bear the brunt of criticism for disputed prices.

There is no method of setting piece work prices or task times more reliable than that of time study, and the absence of the unbiased judgment of the time study observer with reference to conditions surrounding the job, manner in which the workman functions, possible recommendations of a better method of manufacture, as well as other considerations, are losses which immediately affect costs and therefore curtail profits.

Increasing Efficiency of Workmen

The third reason relates to the increasing of efficiency and production, which is one of the prime results attained through time study work. By means of time study, it can be determined which motions on the part of the workman are necessary and which are unnecessary, and standards can be set on this basis and the workman taught how to perform his work with the fewest possible motions and with the best possible efficiency.

If unnecessary motions are therefore eliminated and the work formerly required in the performance of such motions is converted into useful work, we get an increase in production and a consequent increase in earnings on the part of the workman.

To establish equality or uniformity of prices for similar classes of work in various branches of the foundry as outlined in the fourth reason is a result much to be desired and one which can be had only through standardization of working conditions and standardization of equipment.

Two men in different places, even under the same conditions cannot always estimate prices alike, nor can any one man estimate prices exactly the same on different occasions. For this reason it frequently happens that of two pieces nearly alike, one of them has the lower price when it should have the higher, and

this becomes the direct cause of protest and grumbling on the part of the workman. If an attempt is made to cut the price which is too high, serious results may follow.

Time study shows up lost time and enables the observer to compare times of performance of work done in one department with the times of another department doing similar work and to determine the reasons for any discrepancies.

Time study is also the basis for the improvement of equipment and methods with their attendant increase in output as outlined in the fifth reason. In laying out work in the sequence of operations, time studies are particularly valuable in determining standards and so balancing the time for each division of the operation that the work may be handled progressively. In foundry practice the work of gangs may be so apportioned that the task is equally divided between the men.

With reference to the sixth reason in favor of time study work, that of relieving the foreman of the worry connected with price setting and permitting him to concentrate on his first duty, that of managing his department, a great deal may be said. It is obvious that the more duties a foreman has to perform personally, the less are his chances of doing all of them thoroughly and satisfactorily.

The foreman is the key man in industry. His lot should not be made more arduous. He should be relieved of any duties which can be performed to better advantage by persons who specialize in certain well defined functions. The function of rate setting therefore should be delegated to a department charged with that responsibility, and whose work covers this feature in all departments of the plant.

Time Studies Equally Valuable for Other Purposes

In the foregoing paragraphs the discussion has been principally confined to the subject of time study and reasons for its adoption and I have cited some of the benefits which can be derived through its use. However, there are other uses to which time studies may be put, and which make them all the more valuable.

In the work of setting standards for the determination of

task times and hourly production, time studies can be used to good advantage. For instance, a series of charts showing molding time for hand pattern, squeezer and machine molding based upon cubic contents of the flask, serves as an excellent guide for the foreman in checking production and for the time study observer in checking his work. One of a group of such charts is shown in Fig. 1.

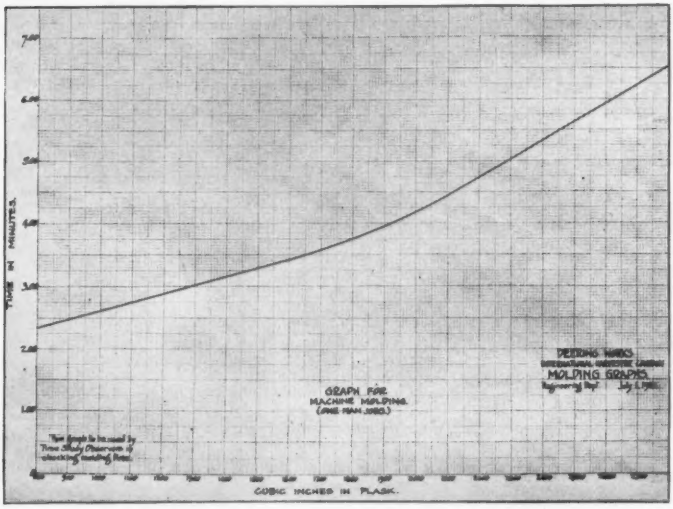


FIG. 1—CURVE USED BY TIME STUDY OBSERVERS IN CHECKING MOLDING TIME ON "ONE MAN" MACHINE MOLDING JOBS

Time studies also show how to plan jobs and arrange work so that lost motion will be eliminated. In industry there is no enemy to productivity worse than lost motion. It causes early fatigue of the worker, consumes valuable time, hinders production and contributes toward high costs. It often represents the dividing line between success and failure, and its elimination will result in the reduction of fatigue, greater production, decreased costs and increased profits.

In its true sense, fatigue has to do with the tiring of the worker and with relaxation sought through application of time

for personal requirements. In order to determine the extent of such natural fatigue and personal necessities and their effect upon production, a series of production studies can be made and resolved into charts showing productive efficiency at every moment of the day, and incidentally those periods of the day when the workers show their best productive effort as well as their periods of least production. One of such charts which

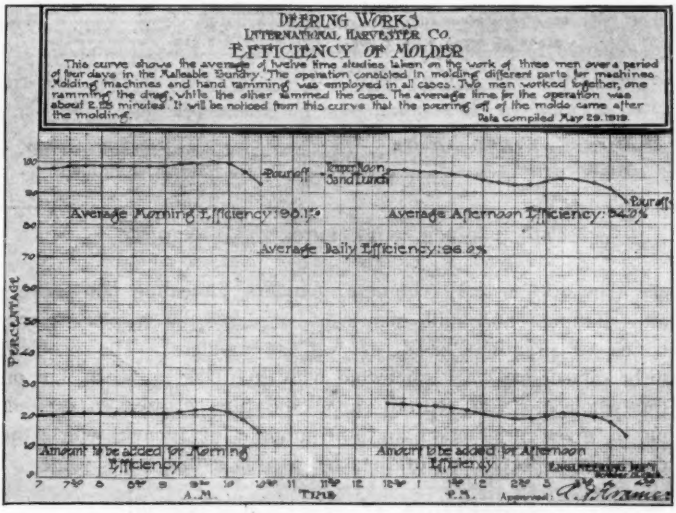
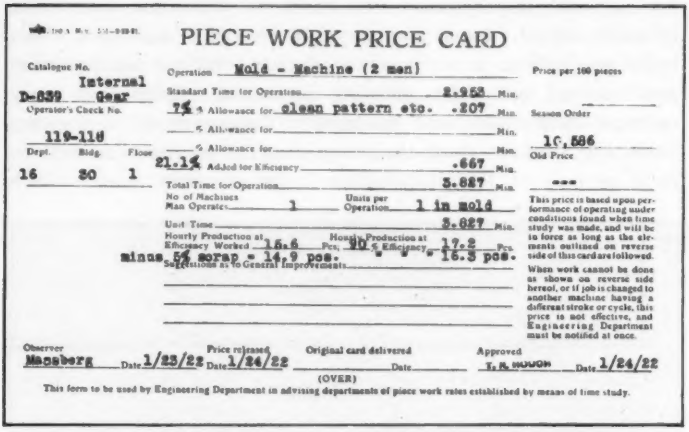

DEERING WORKS
INTERNATIONAL HARVESTER CO.
EFFICIENCY OF MOLDER
This curve shows the average of twelve time studies taken on the work of three men overa period of four days in the Malleable Foundry. The operation consisted in molding different parts for machines. Molding machines and hand ramming was employed in all cases. Two men worked together, one ramming the drag, while the other rammed the cope. The average time for the operation was about 2.25 minutes. It will be noticed from this curve that the pouring off of the molds came after the molding.
Data compiled May 29, 1913.
Average Morning Efficiency: 90.1%
Average Afternoon Efficiency: 84.0%
Average Daily Efficiency: 86.8%
Pouring off
Noon and Lunch
Pouring off
PERCENTAGE
Amount to be added for Morning Efficiency
Amount to be added for Afternoon Efficiency
A.M.
TIME
P.M.

FIG. 2—CURVE SHOWING RELATIVE EFFICIENCY OF MACHINE MOLDERS IN MALLEABLE FOUNDRY

is shown in Fig. 2, represents the relative efficiency of a certain group of molders.

One of the greatest aims of time study is to place in the hands of the foreman and workman suitable instruction cards on which are shown a summary of the time study and detailed information under which the conditions of the study can be reproduced at any time. The value of this card as a permanent record has been proved on many occasions.

There is really no point at which a line can be drawn to limit the use of time studies in the foundry. Floor gangs, pour-



PIECE WORK PRICE CARD

Catalogue No. D-639 Internal Gear
Operator's Check No. 119-110
Dept. 16 Bldg. 30 Floor 1

Operation Mold - Machine (2 men)
Standard Time for Operation 2.953 Min.
7½ % Allowance for clean pattern etc. .207 Min.
% Allowance for Min.
% Allowance for Min.
21.1% Added for Efficiency .667 Min.
Total Time for Operation 3.827 Min.
No. of Machines Man Operates 1 Units per Operation 1 in mold
Unit Time 3.827 Min.
Hourly Production at Efficiency Worked 16.6 Pcs. Hourly Production at 80% Efficiency 17.2 Pcs.
minus 5% scrap = 14.9 pcs. " " = 16.3 pcs.
Suggestions as to General Improvements

Price per 100 pieces

Season Order 10,586
Old Price

This price is based upon performance of operating under conditions found when time study was made, and will be in force as long as the elements outlined on reverse side of this card are followed.

When work cannot be done as shown on reverse side hereof, or if job is changed to another machine having a different stroke or cycle, this price is not effective, and Engineering Department must be notified at once.

Observer Mansberg Date 1/23/22
Price released Date 1/24/22
Original card delivered Date
Approved E. R. WILSON Date 1/24/22

(OVER)

This form to be used by Engineering Department in advising departments of piece work rates established by means of time study.

FIG. 3—PIECE WORK PRICE CARD (FRONT)

ers, truckers, sorters, trimmers, grinders, annealing pot packers and dumpers and mill men can be placed on a piece work, bonus or premium basis, as well as molders. The problem to be solved may vary somewhat with each class of work, but on the whole depends entirely upon the time elapsed in turning out a given production and the amount of money which the employer expects the workman to earn as a just day's wage.

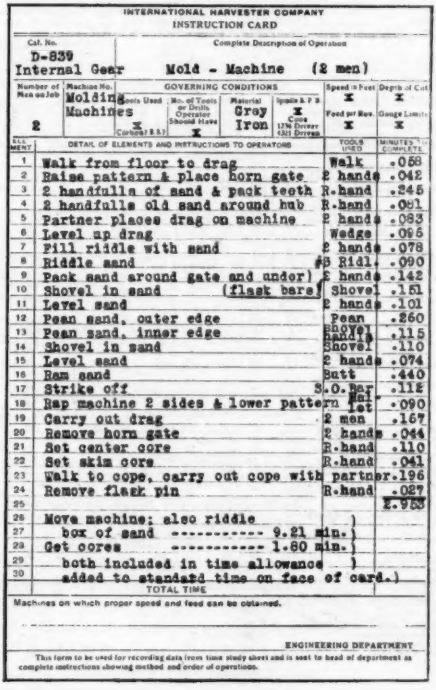
Co-operation of Workman Essential

After prices have been set by time study, they should not be cut unless some changes in operation or equipment are effected, and a change of this character must be a decided one. Just merely transferring a job will not justify a cut. The workman must have confidence in the system or else he will not give his co-operation. Co-operation is the keynote of success in time study work, and the co-operation of the workman is much to be desired. It is good policy to explain to the workman the method used in determining prices by time study, because the more mysterious it appears to him, the harder it is to get his approval and co-operation.

It is always advisable to put on molding work, time study

observers who have had molding experience, because while every observer may be able to take the general run of studies, an experienced molder is best qualified to take foundry studies from which the most value can be obtained.

In most time study organizations will be found men who have natural aptitudes for certain kinds of work which qualify them as experts. Foundry time study observers should be specialists in foundry work, and should have worked as molders on piece work before being selected as members of the staff. I state these facts because I believe in the importance of choosing trained men as observers in the foundry and because a trained man, knowing the thoughts and habits of molders as well



INTERNATIONAL HARVESTER COMPANY
INSTRUCTION CARD

Cat. No. D-839 — Complete Description of Operation: Internal Gear — Mold - Machine (2 men)

Number of Men on Job	Machine No.	GOVERNING CONDITIONS: Tools Used	No. of Tools or Drills Operator Should Have	Material	Speeds & F's	Speed in Feet	Depth of Cut
2	Molding Machines	X (Contact B&S)	X	Grey Iron	X (Core 12% Drover 4&5 Drives)	X Feed per Rev. X	X Gauge Limits X

ELEMENT	DETAIL OF ELEMENTS AND INSTRUCTIONS TO OPERATORS	TOOLS USED	MINUTES TO COMPLETE
1	Walk from floor to drag	Walk	.058
2	Raise pattern & place horn gate	2 hands	.042
3	2 handfulls of sand & pack teeth	R.hand	.245
4	2 handfulls old sand around hub	R.hand	.091
5	Partner places drag on machine	2 hands	.083
6	Level up drag	Wedge	.095
7	Fill riddle with sand	2 hands	.078
8	Riddle sand	#3 Ridl.	.090
9	Pack sand around gate and under)	2 hands	.142
10	Shovel in sand (flask bare)	Shovel	.151
11	Level sand	2 hands	.101
12	Pean sand, outer edge	Pean	.260
13	Pean sand, inner edge	Shovel	.115
14	Shovel in sand	Handle	.110
15	Level sand	Shovel	.074
16	Ram sand	2 hands	.440
17	Strike off	Butt	.118
18	Rap machine 2 sides & lower pattern	S.O.Bar Mallet	.090
19	Carry out drag	2 men	.167
20	Remove horn gate	2 hands	.044
21	Set center core	R.hand	.110
22	Set skim core	R.hand	.041
23	Walk to cope, carry out cope with	partner	.196
24	Remove flask pin	R.hand	.027
25			2.953
26	Move machine; also riddle	)	
27	box of sand ---------- 9.21 min.	)	
28	Set cores ---------- 1.80 min.	)	
29	both included in time allowance	)	
30	added to standard time on face of card.)		
	TOTAL TIME		

Machines on which proper speed and feed can be obtained.

ENGINEERING DEPARTMENT

This form to be used for recording data from time study sheet and is sent to head of department as complete instructions showing method and order of operations.

FIG. 4—INSTRUCTION CARD (BACK OF CARD SHOWN IN FIG. 3)

as their trade secrets, can readily discern whether the person under observation is working efficiently or not.

In making time studies an important part of the task is to gather all information possible pertinent to the work so that an

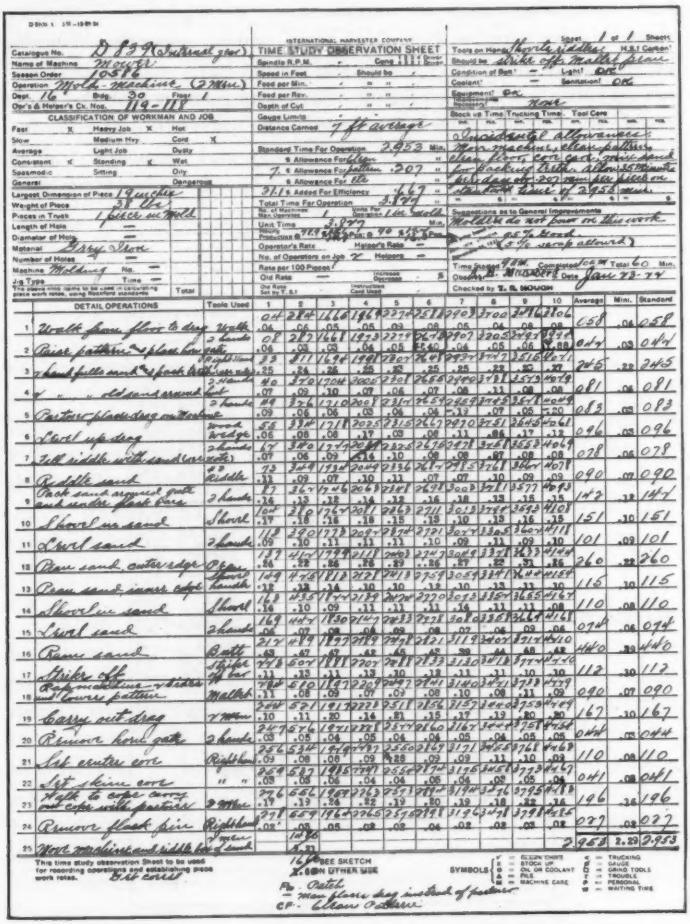


FIG. 5—TIME STUDY OBSERVATION SHEET (FRONT)

intelligent record may be had which will enable the observer to know whether or not the work is necessary, its importance in the production scheme and whether or not conditions can be improved or parts of the operations eliminated or changed to give greater efficiency.

Therefore, it is the first duty of the time study observer

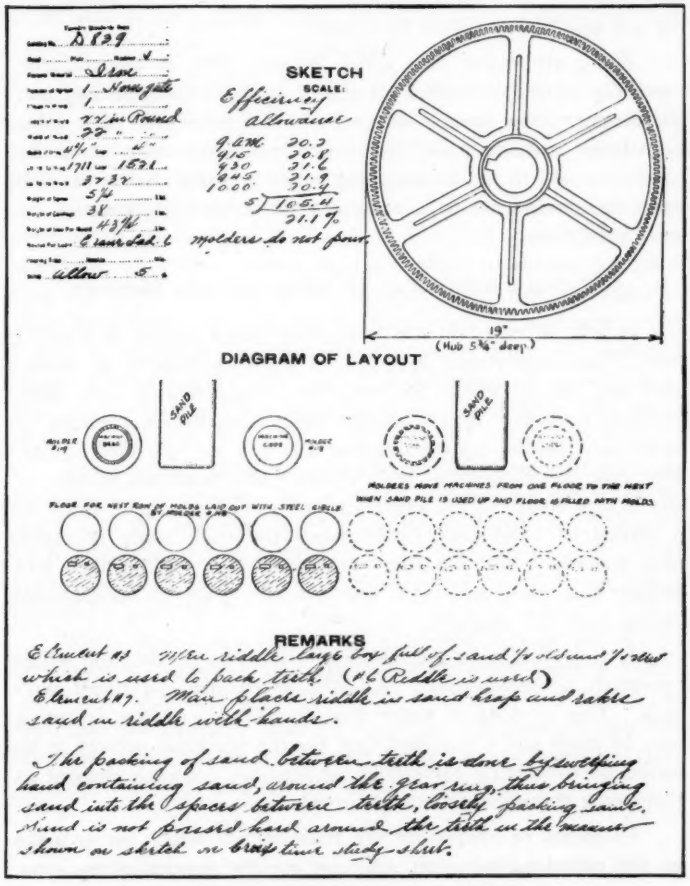

SKETCH
SCALE:
Efficiency allowance
9 A.M. 20.3
9.15 20.1
9.30 21.2
9.45 21.9
10.00 20.4
5 | 105.1
21.1%
molders do not pour
19"
(Hub 5 3/4" deep)
DIAGRAM OF LAYOUT
SAND PILE
SAND PILE
MOLDERS MOVE MACHINES FROM ONE FLOOR TO THE NEXT WHEN SAND PILE IS USED UP AND FLOOR IS FILLED WITH MOLDS
REMARKS
Element #5 When riddle large box full of sand 1/2 old sand 1/2 new which is used to pack teeth. (#6 Riddle is used)
Element #7. Man places riddle in sand heap and takes sand in riddle with hands.
The packing of sand between teeth is done by swinging hand containing sand around the gear ring, thus bringing sand into the spaces between teeth, loosely packing sand. Hand is not pressed hard around the teeth in the manner shown on sketch on brief time study sheet.

FIG. 6—TIME STUDY OBSERVATION SHEET (BACK)

to study the work and make notes of faulty conditions and improper layout of work, as well as other items which lend toward reduction of efficiency. He should examine the flask sections and see that they open and close quickly; that the flask pins are not worn to any extent. He should then see that the molder has a sufficient supply of cores, nails, chills, etc. He should also observe the molder's equipment, see that it is suited for the job and placed within easy reach.

There are many jobs which require few, or no changes, especially those on which experienced molders are working, and the observer can quickly set time study prices on such jobs. Sometimes however, time studies are taken to emphasize faulty conditions and to aid in obtaining better equipment, but in such cases the studies are used only as a basis for the correction of such conditions.

Analyzing Conditions and Dividing Job Into Elements

It will be noted in the time study sheet shown in Figs. 5 and 6 that importance is given to the classification of workman and job, in which the workman is classified as fast, slow, average, consistent or spasmodic; the job as heavy, medium or light; and conditions surrounding the job as hot, cold, dusty, wet, oily, or dangerous; and whether the workman stands or sits at his work. This classification is of permanent value as a record of conditions found when the time study is made, aids materially in selecting suitable fatigue allowances and proper base rate, and is in line with the plan of occupational rating and job analysis.

It is necessary in the taking of time studies, that the whole operation be divided into elements which may be timed with ease. This is done in order that an analysis of the operation may be made and a standard time for the operation arrived at by means of comparing corresponding readings for each element as they recur throughout the cycles studied.

Elements of operations are those details which go to make up the complete operation, and are usually terminated by some definite movement on the part of the workman such as laying

down one tool and picking up another. These movements are known as "cut off points" and make it easy for the time study man to observe the intervals while reading his watch and making entries on the time study sheet. The more finely the whole operation is divided into elements, the better can the operation be analyzed and the standard time built up.

Piece Work Price Based upon Standard Time, Production and Base Rate

The standard time, to which are added all necessary allowances for fatigue, efficiency, and incidental work, constitutes the basis upon which is determined the production which the workman must attain to earn his base rate.

In setting piece work prices the hourly base rate has a direct relation to the time study price and to the earnings of the workman. It is the medium used to convert production per hour into the piece work price, and in order to obtain an equitable piece work price we must first have an equitable base rate. The hourly base rate is that amount of money which the employe should receive for the satisfactory performance of a given duty, and is a factor of first importance in establishing just piece work prices.

The equitable base rate can be established only by an analysis of the occupation, by which is determined the value of the job to the industry, based upon the skill required, difficulty of training, hazard involved, and other considerations. It should always be founded on the basic principle of "a just wage for a just day's work."

When base rates are set by a method having this as its fundamental principle, earnings resulting from such a policy will vary, depending upon individual effort. It will be readily seen that the desirable class of employes will earn at least the base rate, the good class will earn more and the excellent class of employes will earn a still higher wage.

Occupational Rating Plan

In the occupational rating plan, the fundamental idea is that of remuneration for day and piece work occupations in pro-

portion to their industrial worth, rather than for the personal attainments of those who happen to fill the occupations. Thus in foundry work if we study the duties and qualifications of the several occupations, we find enough difference in them to justify the rating of one group of occupations higher or lower than some other groups.

In the list of foundry piece work jobs there is a range in values from the foundry laborer in the lowest group to the floor molder in the highest group. In order that this division of work into groups may be noted, a few of the foundry occupations are presented on the opposite page.

As will be observed from this list, each occupation has a specific name and number, which greatly facilitates the hiring, placing and proper rating of men.

Job Analysis Card

For purposes of permanent record, a job analysis card is used, similar to that illustrated in Figs. 7 and 8. Upon this card are recorded the duties required and qualifications desired of workmen filling the occupation. Space is provided upon the card for the recording of the name and number of the occupation, the group in which it belongs, and the departments in which it occurs. Checkmarks in small squares designate the desirable qualifications as well as nature and conditions of work. Suitable space is provided for comparable occupations, for a description of machine tools operated and personal hand tools required, and provision is also made for permanent rate data pertaining to the occupation. This permits the employment manager at all times to consult the record rather than trust to memory for figures.

On the reverse side of the card are shown the specific duties of the job as well as the necessary employe qualifications.

Progress In Industry Demands Time Study Methods Be Adopted

In the introductory remarks of this paper, the thought was presented that time study because it is an invaluable adjunct to the manufacturing business required no sponsoring by the writer

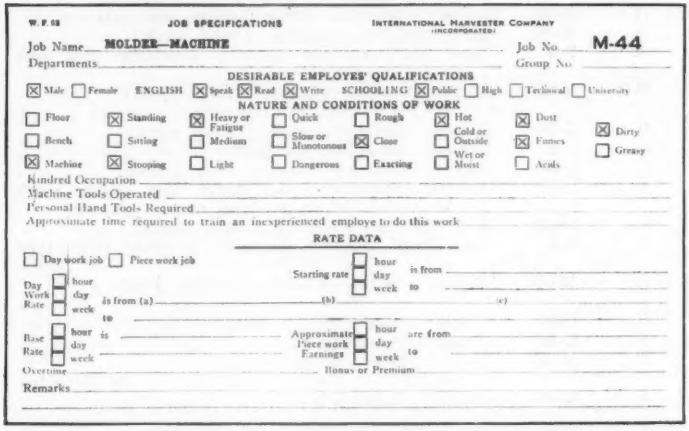
Foundry, Mill Room and Core Room Piece Work Occupations

(Classified according to occupational rating plan.)

Group	Job No.	Occupation
A	C-28	Chipper—hand (light work)
A	C-42	Coremaker—simple light cores
A	G-31	Grinder operator—rough (light work)
A	L-3	Laborer—annealing pot dumper
A	L-18	Laborer—casting trimmer
A	L-21	Laborer—charger (malleable iron melting furnace)
A	L-35	Laborer—foundry (sand cutter and shaker out) Light molds or working after pouring
A	L-60	Laborer—wheeler (miscellaneous material)
A	M-31	Mill operator—tumbling (light work)
A	S-4	Sand blast machine operator—tumbling mill type
B	M-43	Molder's helper—machine (simple jobs)
C	G-30	Grinder operator—rough (heavy work)
C	L-4	Laborer—annealing pot packer
C	L-34	Laborer—foundry (molten iron pourer)
C	L-35	Laborer—foundry (sand cutter and shaker out) Heavy molds or working during pouring.
C	M-30	Mill operator—tumbling (heavy work)
C	S-4	Sand blast machine operator—rotating table type
D	M-43	Molder's helper—machine (major jobs)
E	C-29	Chipper—hand (heavy work)
E	C-30	Chipper—pneumatic
E	M-42	Molder—floor (annealing pot)
F	M-43	Molder's helper—floor
G	C-43	Coremaker (all round) Major cores but not for engine parts.
H	C-43	Coremaker (all round) Major cores for engine parts.
H	S-3	Sand blast hose operator
I	C-46	Core setter—mold
I	M-37	Molder—bench—simple work
I	M-39	Molder—brass—simple work
I	M-44	Molder—machine—(simple jobs)
I	M-47	Molder—squeezer
J	M-44	Molder—machine (major jobs)
K	M-37	Molder—bench—major work
K	M-39	Molder—brass—major work
L	C-48	Coresetter—engine multiple cylinder block
L	M-40	Molder—floor

for the application of its principles. Nevertheless, it may be well to state that it is highly regarded by up-to-date business enterprises as most essential and by them is used for every means for which it has value.

Where the installation of a time study department is contemplated, the personnel should be such as to inspire the confidence of those concerned, and cause them to cheerfully relinquish the price setting activity to such organization. Therefore, it is obvious that such personnel for time study work in found-



W. F. 68 JOB SPECIFICATIONS INTERNATIONAL HARVESTER COMPANY (INCORPORATED)

Job Name MOLDER—MACHINE Job No. M-44

Department Group No.

DESIRABLE EMPLOYES' QUALIFICATIONS

☒ Male ☐ Female ENGLISH ☒ Speak ☒ Read ☒ Write SCHOOLING ☒ Public ☐ High ☐ Technical ☐ University

NATURE AND CONDITIONS OF WORK

☐ Floor ☒ Standing ☒ Heavy or Fatigue ☐ Quick ☐ Rough ☒ Hot ☒ Dust ☒ Dirty

☐ Bench ☐ Sitting ☐ Medium ☐ Slow or Monotonous ☒ Close ☐ Cold or Outside ☒ Fumes ☐ Greasy

☒ Machine ☒ Stooping ☐ Light ☐ Dangerous ☐ Exacting ☐ Wet or Moist ☐ Acids

Kindred Occupation

Machine Tools Operated

Personal Hand Tools Required

Approximate time required to train an inexperienced employe to do this work

RATE DATA

☐ Day work job ☐ Piece work job

Starting rate ☐ hour ☐ day ☐ week is from

Day Work Rate ☐ hour ☐ day ☐ week is from (a) (b) (c) to

Base Rate ☐ hour ☐ day ☐ week is

Approximate Piece work Earnings ☐ hour ☐ day ☐ week are from to

Overtime Bonus or Premium

Remarks

FIG. 7—JOB ANALYSIS AND SPECIFICATION CARD USED IN OCCUPATIONAL RATING (FRONT)

ries must include observers who besides having had molding experience, are resourceful, tactful, possess initiative and have an analytical turn of mind.

Time studies taken by observers having such qualifications are not only of great value as a price setting medium, but when comparing operations between different shops. Discrepancies in more inefficient methods can be readily detected and corrected when there is a time study available showing the correct method in detail.

Price setting by a duly appointed person or organization is as much a sign of advancement as any of the other moves

which progress in industry has made necessary, and should not be regarded as a curtailment of authority or responsibility of anyone concerned.

Consider the older method of setting a price on a job and leaving the molder to make wages or quit, or in some instances earn more money with greater ease than his neighbor who might have a "tighter" price, and contrast it with the time study method of setting standards and teaching the molder how to perform the work in the allotted time. Under the latter

Job Name **MOLDER—MACHINE** Job No. **M-44**

THE DUTIES OF THIS JOB ARE:

To make Molds of sand operating a Molding Machine, carrying molten iron and pouring same into molds.

NOTE No. 1: At the various Works the duties involving carrying and pouring the molten iron vary in extent.

NOTE No. 2: Must exercise a "safety first" attitude in the handling of molten iron and conform to Company's rule requiring the use of leggings which are furnished gratis. It is also suggested, for "safety first" reasons, that he wear regulation Molder's boots which are supplied, at cost price by the Company.

THE NECESSARY EMPLOYE QUALIFICATIONS TO FILL THIS JOB ARE:

(1) Must be capable of taking care of and operating a Molding Machine making sand molds for various kinds and sizes of castings.

(2) Must be familiar with the proper tempering and mixing of facing and molding sands.

(3) Must be handy in the use of the Molder's tools.

(4) Must be capable of skillfully setting the cores, and lifting, placing and clamping the molds and weighting same.

(5) Must be capable of carrying molten iron in ladles and pouring into molds.

(6) Must be an active, careful workman, observant to avoid accidents, physically strong and able to endure the heat and general foundry conditions.

(7) Must be capable of and willing to follow instructions and he should have had previous similar or other foundry experience.

Remarks Before starting this job the employe must be instructed as to any dangerous or hazardous conditions in connection with his duties and made familiar with all "safety first" rules.

FIG. 8—JOB ANALYSIS AND SPECIFICATION CARD (BACK)

plan, at the end of the day the molder may accomplish more and with less fatigue, and he is satisfied that fair consideration was given him in setting his price, and he will be more contented.

Therefore with the relief from the duty of price setting, the value gained from the services of a specialist in foundry details, advantages gained through the increase in production as a result of carefully made time study investigation, there should no longer be any ground for real objections to the introduction of a well ordered, properly equipped department to take time studies, properly catalog occupations and justly and openly rate jobs in accordance with their industrial worth.

Eye Protection and Safe Clothing in the Foundry

By Buell W. Nutt, Cleveland

A short time ago we were shocked and horrified to read the grewsome details of the collapse of a roof of the theater in Washington which resulted in the death of 110 persons and which seriously and permanently injured many more. Three investigations were started to try to fix the blame, one of them directed by congress. The whole country was aroused over the calamity and newspapers in every quarter printed columns about the tragedy brought to the homes of the 110 victims whose lives were snuffed out without warning and demanded that this sort of thing be stopped. One of the Cleveland newspapers printed a list of the great disasters of a like nature that had occurred in the past 50 years. The author cannot remember all of the figures, but the list contained such occurrences as that of the Iroquois theatre in Chicago which resulted in the death of 575 and that of the Conway theater in Brooklyn which took the lives of 245. This set the author to thinking and he took out his pencil and totaled up the entire list. It amounted to 1141 which had come to violent death in the period of 50 years. Yet, in the United States we killed a number 75 times as great as this total in one year through accidents! If we add to this number the tens of thousands who are not killed outright but who are permanently injured each year and to this number add the hundred of thousands who are temporarily injured each year, we have a number large enough which if massed together 10 abreast and marched in review would take 24 hours to pass a given point. We kill more men in the industries of this country each year than were in the American army during the whole time of our participation in the war.

The reason that the general public does not rise up in wrath and protest that this slaughter and suffering be stopped is simply that it is a rare occurrence for, say 110 men to be killed in any one plant at one time. In the industries they are killed

usually one at a time and naturally the killing of one man does not impress us like the killing of 110 men at a time and we pass by the incident with perhaps the remark "another poor fellow killed."

Loss of Lives, Money and Productive Power Tremendous

Slowly business men and employers have come to realize that the country is standing a tremendous loss each year, a loss in lives, in money and productive power of labor, and this has resulted in a great deal of thought and study of the subject of "How to Prevent Accidents." Every different kind of an industry presents its own hazards and each individual plant its special problems.

As foundrymen you are naturally interested in how to prevent accidents in the foundry, mill and metal working plants, and while the author does not intend to cover the general subject of safety in the foundry, he will endeavor to present some helpful information on one branch of it, that is, eye protection and safe clothing for workmen.

Of all the nonfatal accidents which occur, eye accidents are among the most numerous and most costly of all. It is estimated that at least 20 per cent of all these nonfatal accidents are eye accidents, and that of the eye accidents, probably 28 per cent result in the loss of one eye and 10 per cent in the loss of both eyes, while many of these accidents impair the vision to a lesser or greater degree, cause a great deal of suffering, result in much lost time, and are a very great expense to the employer, and often to the community. The sad part of all this is that eye accidents, of all accidents, are probably the easiest to prevent, and it is conservatively estimated that at least 95 per cent of them can be eliminated by the use of proper goggles, or by the use of various types of masks, hoods, and helmets.

Ascertains Employe's Objections to Goggles

The author has visited hundreds of plants in the past six years that he has been interested in eye protection and while at first it was sometimes difficult to convince an employer to provide goggles for his employes, most employers now do not

hesitate to buy goggles. The greatest problem with them today seems to be the question of how to get the men to wear the goggles after they have been supplied. A great many workmen in all kinds of plants interviewed in an endeavor to find out why they do not want to wear goggles, and their objections have been sifted down to about three general complaints as follows:

1. They are afraid that the glass may be broken and driven into the eye.

2. They complain that goggles are uncomfortable and hurt their noses, cheeks and ears.

3. They complain that goggles give them headaches or prevent them from seeing properly.

Let us consider these three complaints:

First we have fear of broken lenses. No workman now need be afraid to wear goggles of the better or standard grades, because the frames are substantially made and the lenses used are especially ground to withstand heavy blows without breaking. Two general types of lenses are used for chipping and grinding goggles; one type being an optical glass which is ground, polished and especially annealed which makes it a great deal stronger than ordinary glass, and the second type being a lens constructed of two separate sheets of glass between which a sheet of celluloid is placed, the three being welded together into one solid lens. A lens of this character even when cracked by a heavy blow will not separate. Therefore, if workmen are provided with goggles of a standard make, they may be assured that they will have no trouble from broken glass being driven into the eye with the resultant loss of vision.

Adjustment of Goggles to Individual Workmen Is Essential

Second, we have the complaint of discomfort, and in the author's judgment this is the biggest obstacle of all to the wearing of goggles. We cannot expect men to wear goggles that are uncomfortable and which hurt their noses, cheeks or ears. To eliminate this complaint, the right type of goggles must be

selected for the particular work in hand. For grinders, chippers and similar operators the spectacle form of goggles fitted with side screens is the best. It is also best to select one which may be readily adjusted, so that it may be easily fitted to the contour of the nose, cheek and face. No two faces are just alike, and to make goggles comfortable care must be exercised to see that they are properly fitted. Adjusting the nose piece or temples usually will change an uncomfortable goggle to a comfortable one, and one which workmen will wear without complaint. It is good practice to have one man in each plant who has had some instructions in the use and care of goggles supervise the distribution of goggles, so that he can see that each man is properly fitted and can look after the repairs and sterilizing of goggles.

Third, we have the complaint that goggles cause headaches and prevent clear eye sight. The headache part of this complaint frequently is due to the poor adjustment which causes undue pressure on the nose or cheeks. Proper adjustment will overcome this. Sometimes men will also tell you that they cannot see plainly when wearing goggles. As a matter of fact the lenses in the better grade goggles never obscure vision and will neither add not detract from a man's vision—the chances are that the man who makes this complaint has defective eye sight. A man who has poor vision is not always a safe man to have around a plant, neither is he efficient, as eye strain produces fatigue, dizziness, headaches, and causes a slowing up of the worker, as he cannot see his work properly. It also results in a drain of nervous energy with the result that the functions of other parts of the body must suffer in consequence, and thereby lower the vitality and efficiency. After the age of 35 to 40 years, the near-point vision of most people begins to dim, and when this has started the only way to overcome it is to have lenses fitted, which, in a sense, restores the vision to its former keenness. In those below 35 years of age other defects of vision may occur which may be corrected just as easily by proper lenses. To give a man goggles fitted with plain glass and expect him to use them, regardless of the fact that he may have

poor vision, many times places him under a handicap. Many complaints that goggles cause headaches, dim vision or that they hurt the eyes can be traced to this source.

Loss of One Eye Impairs Eyesight More Than 50 Per Cent

Man is equipped with what we call binocular vision; that is, he uses both eyes at the same time, to look at the same object, and by this method is enabled more accurately to tell direction and judge distance and the size of objects. The loss of an eye, therefore, upsets the whole scheme of his vision, and as a result he not only loses 50 per cent of his sight, but far more, as the remaining eye cannot function properly by itself. Therefore the ability to judge direction and distance correctly is largely lost to the individual with only one eye. Thus, too, many people who have normal vision in one eye and defective vision in the other are not aware of the fact, and frequently poor vision in both eyes is not detected. Such employes are a source of danger, not only to themselves, but to their fellow workmen. It pays to know that men in your employ have good eyesight, and it pays to provide goggles fitted with corrective lenses when you find a workman suffering from poor vision, because improved vision not only makes a more proficient worker, but it often overcomes the objection to wearing goggles. The amount of vision a man has, may be determined easily by means of a simple chart which can be used by any clerk in the employment department.

Certain kinds of work exposes the eyes of workers to intense heat and light. Welders, metal pourers, furnace men and others, therefore, must be provided with goggles or masks containing specially colored lenses to keep out the dangerous rays of light which are present in all forms of artificial as well as natural light.

For sand blasting and other dusty operations there are available hoods of various styles which keep out dust, dirt or sand. Likewise respirators and gas masks of various types should be provided for men subject to dust, fumes, gas or smoke. Giving a little thought to the proper selection of the type of eye protection required and some personal attention in

seeing that men are properly fitted will usually solve the problems of eye protection.

Safe Clothing Is Essential to Prevent Accidents

The question of safe clothing in the foundry means first the elimination as far as possible of thin, ragged, greasy, loose, and baggy clothing, and worn-out or laced shoes. Men should be urged to wear the one-piece suit where possible, as it eliminates much of the hazard from loose, ragged clothing. Fireproofed duck suits of the one-piece variety make the safest and most practical suits to use, as they will shed sparks and small spatters of metal and will not burn readily. Asbestos suits also can be secured, and are sometimes necessary. Safety shoes are also essential and at any rate the use of lace shoes should be prohibited. The proper leggings should also be provided to prevent the burning of legs and feet. There are numerous types of leggings which are practical and which absolutely will prevent burns.

For workmen handling ladles, or hot metals of any kind, also for welders and other operators, asbestos gloves, leg pads and aprons are available, and should be provided. It may cost a little to provide these things, but it never costs as much as paying for burns or other accidents which may happen. Many cuts and abrasions of the hands can be eliminated by providing leather gloves of special designs. It is frequently necessary to provide also sleevelets where special protection is required for a man's arms.

An example of what may happen when proper clothing is not provided is illustrated by a recent occurrence in a foundry in St. Louis. A workman in the employ of the company was pouring red hot metal into molds. This resulted in a shower of sparks and a spatter of red hot metal. In order to protect his clothing, the man had secured a burlap bag which he tied about his body like an apron. No cord or string being handy, he fastened the bag around his body with a piece of wire. The bag had become greasy and oily and during one of the pouring operations a spark lodged in it and in a few seconds he was enveloped in flames. Fellow workmen tried to extinguish them

but the bag was wired to the man's body and before it could be removed he was so badly burned that he died in great agony a few hours later. The man lost his life, his wife was made a widow, his seven minor children were left without his protection and it cost the company a good several thousand dollars, all be-because he had not been provided with a fireproof suit or an asbestos apron that at most would not have cost over $5.00.

Do not let a man work around your plant with ragged clothing, worn-out shoes, or covered with makeshift protection. The best protection you can get is none too good and its cost is many times less than accident costs. Whatever is paid out in money as compensation never squares the account because a human suffering and death can never be measured by a dollars and cents standard.

Report of Safety, Sanitation and Fire Prevention

At the time of the convention held in Columbus, O. two years ago the report of the Committee on Safety, Sanitation and Fire Prevention, covering the activities of the committee up to that time, set forth that after considerable correspondence a joint meeting of the committee of the American Foundrymen's Association and the National Founders Association, together with representatives of different organizations, government and state department representatives, etc., called in upon the invitation of the A. F. A. and N. F. A. and at the suggestion of the secretary of the A. E. S. C., had been held in Buffalo, N. Y. At this meeting the Code had been well considered, and after revision, which met the approval of all those present, had been submitted to the A. E. S. C. for consideration with view to the adoption by that body as a standard.

This approval was with-held as the personnel of the joint committee had not been formally passed upon previous to our meeting in Buffalo.

Following the matter, your chairman once more called a meeting and as a result of invitations sent out, the gentlemen whose names follow met in Buffalo, February 14, 1922.

Sponsors:

H. J. Boggis, Chairman, N. F. A. Committee on Safety and Sanitation

B. D. Fuller, Chairman, A. F. A. Committee on Safety, Sanitation and Fire Prevention, A. F. A.

W. H. Barr, President, National Founders Association.

Sectional Committee:

Edward Keener, President, Buffalo Co-operative Stove Co.

G. E. Sanford, General Safety Inspector, General

Electric Co., representing Society of Safety Engineers.
B. C. Riffel, National Bureau of Casualty & Surety.
Fred G. Lang, U. S. Bureau of Standards.
Dr. R. C. Williams, U. S. Public Health Service.
A. S. McAllister, Sec't. A. E. S. C.

The Code was once more considered very carefully word by word,. revised somewhat and rearranged and copies sent to the members of the committee who were unable to attend and their approval secured.

The full committee, taking part in the formation of the Code which committee was finally approved by the A. E. S. C. was as follows;

W. H. Barr, Pres. N. F. A., Buffalo, N. Y.
H. J. Boggis, Chairman, N. F. A. Committee Safety & Sanitation, Cleveland, Ohio.
B. D. Fuller, Chairman, A. F. A. Committee Safety Sanitation & Fire Prevention, Niagara Falls, N. Y.
H. S. Echtenach, Safety Engineer, Dep't of Labor & Industry, Harrison, Pa.
J. P. Frey, Editor International Molders Journal, Cincinnati, Ohio, representing, Dep't of Labor U. S. A.
W. W. Green, Employees Mutual Insurance Committee New York City.
F. J. Hartman, Industrial Board, Dept. of Labor & Industry, Harrison, Pa.
H. E. Hassel, American Steel & Wire Co. Pittsburgh, Pa.
F. G. Lange, Bureau of Standards, Washington, D. C.
H. D. Miles, Buffalo Foundry Co., Buffalo, N. Y.
B. C. Riffel, National Bureau of Casualty & Surety Underwriters, New York City.
G. E. Sanford, Genr'l Electric Co. Lynn, Mass.
R. C. Williams, U. S. Public Health Service, Washinton, D. C.

The revised code is now before the A. E. S. C.* and will, no doubt, be finally approved and adopted as a standard in the near future. When this approval has been formally received, the code as rearranged will be reprinted and made a matter of record by our body.

Benj. D. Fuller (Chairman of committee, Safety, Sanitation & Fire Prevention).

*The American Engineering Standards Committee has now approved the code as revised and adopted it as a standard.

Technical School Foundries

By J. D. HOFFMAN and R. E. WENDT, Lafayette, Ind.

The application of science to the industries in past years has been more or less voluntary on the part of the manufacturers of the country. The natural resources of this country have been so vast and so varied that great waste has occurred as a natural result of the process of wholesale elimination in selecting the best, and close refinements were not considered necessary. In recent years, however, the fact of the urgent need of the conservation of these natural resources has been so impressed upon the people that industries of all kinds are being reconstructed along lines of scientific and economic production.

One of the influences aiding this development toward economy has been and is the technical school. Here materials are analyzed, their physical properties charted and fundamental facts and laws established concerning them. The technical school has had for its aim the connecting up of the theoretical training in the sciences with the practical training in the drawing rooms, shops and power plants of the country, and the harmonizing of these two forces toward the one aim, solely, the development of a young manhood capable of assisting in this reconstruction and of being absorbed into the industries of the country with the least economic loss.

Whatever degree of progress has attended this educational scheme in the past, and we have reason to believe this progress has been marked, there still is great improvement to come. The theoretical work of the class room has been supplemented by physical experiment and research in the materials laboratories, and by the more practical work of the shops and drawing rooms in these institutions. However, with all the effort thus far expended the schools, chiefly because of lack of funds to maintain such work, have given only a small amount of study to the engineering features of shop and other manufacturing processes.

One of the most backward of these important lines is that of the foundry. In the manufacturing world, the foundry is the place where great losses may be incurred or great economies may be effected. In this regard it compares somewhat with

SCHOOL FOUNDRY DATA

Name of School----------

Located at----------

Type of School. Engineering. Trade.

How many students were enrolled in the foundry course last school year?----------

What year students take foundry work?----------

How many hours in the course?----------

How many hours to the period?----------

Largest number of students to any one class----------

Number of students to one instructor----------

Underline the type of castings made. Gray-iron. Steel. Brass. Aluminum.

What size cupola do you use? Dimension on the inside of cupola----------

What other type furnace besides cupola do you use?----------

How many heats were poured during last school year?----------

Type of castings made----------

Maximum size of castings made----------

Total amount of metal melted during school year----------

Total number of pounds good castings made----------

Total number of pounds unfit castings made----------

Number of pounds of iron in sprues, risers----------

Surplus metal----------

Loss in melting----------

What melting ratio did you obtain?----------

Do you prefer to employ practical men or college graduates as teachers?

Date----------

By----------

FACSIMILE OF QUESTIONNAIRE SENT TO 71 TECHNICAL SCHOOLS

the power plant of any institution where the first reductions from the potential heat value of the coal to the active heat of the steam may sustain greater losses than can possibly be made up by all the mechanical refinements in the succeeding processes. Although the tardy recognition of its importance in the field of manufacture has delayed the founding industry probably more than other lines, it is now being studied commercially and is looking forward to a rapid scientific development.

Questionnaire Sent to Schaol Foundries

Many letters have been addressed to the technical schools asking what the schools are doing to help out the situation.

Table I

ENROLLMENT AND ORGANIZATION

School number	Number of students in foundry courses	Number hours in course	Hours to period	Number students to class	Number students to one instructor
1.....	61	45	3	20	20
2.....	570	36	2	32	..
3.....	109	60	3	20	8
4.....	..	90	2.5	26	13
5.....	283	144	4	40	14
6.....	250	72	3	26	13
7.....	150	54	3	20	20
8.....	110	51	3	20	20
9.....	200	48	3	20	20
10.....	505	60	3	72	20
11.....	162	..	4	23	8
12.....	61	36	3	22	22
13.....	40	37.5	2.5	20	20
14.....	40	45	3	24	24
15.....	109	80	4	18	18
16.....	100	64	4	20	20
17.....	132	72	3	22	22
18.....	598	96	4	60	15
19.....	60	20	..	10	10
20.....	120	50	3	8	8
21.....	100	33	3	28	28
22.....	108	60	2	30	20
23.....	87	72	3	25	25
24.....	12	80	4	12	12
25.....	358	45	3	37	19
26.....	36	54	..	24	24
27.....	25	..	4	13	13
28.....	120	..	3	18	18
29.....	87	108	3	20	20
30.....	150	32	2	20	20

Note:—Blank spaces indicate no report.

These letters naturally had to be answered in a general way only, because no comparative data were at hand. Therefore, in order to obtain first hand knowledge of what is being done by the technical schools in the line of founding a questionnaire shown on page 4, was sent to 71 technical schools asking for information. Out of this number sent out, 50 were answered and returned. Of the 50 replying 30 operate foundries, 20 keep a partial record of work performed and only 10 keep a complete record as will be shown in the tables.

The schools were arranged alphabetically, then numbered from 1 to 30, and listed in Table I. The 30 schools had a total

Table II

EQUIPMENT AND CLASS OF WORK

School Number	——Metals Poured—— Gray iron	Brass	Aluminum	Size cupola inches	Brass furnace	Maximum weight casting pounds
1.....		x	x	54	x	5
2.....	x	x	x	42 & 24	x	1200
3.....	x	x	x	24	x	700
4.....	x	x	x	20	x	600
5.....	x	x	x	24	x	990
6.....	x	x	x	30	x	1200
7.....	x	x	x	15 & 20	x	720
8.....	x	x	x	20	x	1100
9.....	x	x	x	18 & 27	x	1000
10.....	x	x	x	23	x	....
11.....	x	x	x	32	x	500
12.....	x	x	x	24	x	200
13.....	x	x	x	15		20
14.....	x	x		24	x	250
15.....	x	x	x	22	x	150
16.....		x	x	20	x	....
17.....	x	x	x	20	x	1000
18.....	x	x	x	24	x	200
19.....	x			22	x	500
20.....		x	x	..	x	60
21.....	x	x	x	28	x	1000
22.....	x	x	x	26	x	225
23.....	x	x	x	22	x	100
24.....	x	x	x	24	x	250
25.....	x	x	x	24	x	350
26.....	x			30		100
27.....	x	x	x	20	x	600
28.....	x	x	x	26		600
29.....	x	x	x	22	x	290
30.....	x	x	x	26	x	700

enrollment of 4742 students in the foundry courses during the year 1920-21. The largest enrollment in any one school was 598 and the lowest was 12. The total length of time devoted to foundry work ranged from 20 to 144 hours. The students work from two to four hours in any one day and from one to three days per week. There were from eight to 72 students working in one class and one instructor was employed on the average for every 18 students.

Table II shows the kind of castings made, size of cupolas used and the maximum weight of single castings. Most of the schools make gray iron, brass and aluminum castings. Only one school reported making steel castings.

Table III

SCHOOL FOUNDRY DATA

*Performance and Results**

School Number	No. of heats	Metal charged	Good cast'gs	Bad cast'gs	Metal in sprues	Surplus metal	Loss in melting	Melting ratio
1.....	..	....	....	....	.....	....	....	..
2.....	30	60,000	44,496	7,833	5,500	....	1,200	7
3.....	30	50,000	30,000	15,000	3,000	....	2,000	7.5
4.....	34	10,000	....	....	....	....	....	..
5.....	24	88,000	37,000	11,000	24,000	8,000	8,000	9
6.....	24	80,000	....	....	....	....	....	..
7.....	36	38,000	....	....	....	....	....	..
8.....	28	43,345	25,027	2,998	4,250	6,484	4,586	5.5
9.....	20	30,000	22,200	1,000	2,600	1,500	2,700	5.5
10.....	17	11,000	....	....	....	....	....	4
11.....	24	....	....	....	....	....	....	..
12.....	3	5,400	2,000	....	....	....	....	4
13.....	10	4,000	....	....	....	....	....	..
14.....	6	3,000	....	....	....	....	....	5
15.....	30	58,086	22,680	7,560	17,580	7,500	2,766	6.5
16.....	..	....	....	....	....	....	....	..
17.....	28	82,000	62,139	3,116	10,330	4,146	2,269	5.4
18.....	30	62,700	33,431	1,973	19,286	3,228	4,782	4.8
19.....	4	6,000	....	....	....	....	....	..
20.....	..	....	....	....	....	....	....	..
21.....	15	30,000	....	....	....	....	....	..
22.....	8	8,400	4,284	338	1,636	1,680	462	3
23.....	6	24,000	6,000	8,000	....	....	....	4
24.....	..	3,000	....	....	....	....	....	..
25.....	13	20,800	13,800	1,200	3,900	1,600	260	3.2
26.....	?	....	....	....	....	....	....	..
27.....	12	5,000	....	....	....	....	....	.
28.....	10	8,000	4,000	1,000	500	300	2,200	9
29.....	12	24,046	8,899	4,607	(8,599)		1,941	..
30.....	10	16,000	14,500	700	700	....	....	8

*Weights given in pounds.

The cupola furnaces used range in sizes from 15 to 54 inches on the inside of the lining. The 24-inch cupola seems to be the most popular for school work. For melting the non-ferrous metals, almost all kinds of furnaces built to melt this metal are used except the electric furnace. However, some of the schools are planning the installation of electric furnaces as soon as their funds will permit. Small to medium sized castings are made by all the foundries, the sizes ranging from a few ounces to about 1200 pounds.

In Table III the performance records of the 30 schools operating foundries are shown. It will be noticed that five schools do not keep any record of their melt or performance, 15 have only a partial record and 10 keep a complete record. This seems to indicate that most of the schools are as yet not operating their foundries upon a scientific basis.

Table III also shows the number of heats taken during the year, the total metal charged by each school, the number of pounds of good and bad castings made, the amount of metal contained in sprues and risers, the surplus metal, the loss in melting and the melting ratio.

Variations in Melting Losses

These data show a wide difference in the loss in melting and the melting ratio. It was thought that probably some did not understand the question, so considerable correspondence was carried on to ascertain whether or not this was true. The answers in every case were that they understood the question. However, the melting ratio seems to indicate that in many cases this was based on the iron and coke charged above the bed charge instead of the total metal melted to the total coke burned. A melting ratio of 3 to 1 seems to be pretty low and a melting ratio of 9 to 1 is somewhat high for small cupolas and especially in small heats.

In Table IV the results obtained by the 10 schools keeping complete records are shown. The percentages are based on the total amount of metal charged. Here there is a wide variation in the results obtained. One school reports as high as 75.8

Table IV

School number	Percentages Based on Total Metal Charged: Good castings	Bad castings	Sprues risers	Surplus metal	Loss in melting
3.....	60.0	30.0	6.0	...	4.0
5.....	42.0	12.5	27.3	9.1	9.1
8.....	57.7	6.9	9.8	15.0	10.6
9.....	74.0	3.3	8.7	5.0	9.0
15.....	39.1	13.0	30.2	12.9	4.8
17.....	75.8	3.8	12.6	5.0	2.8
18.....	53.4	3.1	30.8	5.1	7.6
22.....	51.0	4.0	19.5	20.0	5.5
25.....	66.5	5.8	18.8	7.7	1.2
28.....	50.0	12.5	6.2	3.8	27.5

per cent of good castings and one reports only 39.1 per cent. The bad castings show a wide difference. One reports having only 3.1 per cent bad castings and one had as high as 13 per cent. The percentages of sprues and risers show that the highest ran as high as 30.8 and the lowest as low as only 6.2 per cent. The surplus metal ranges from 3.8 to 20 per cent. In the percentage of loss in melting there seems to be a great difference, ranging from only 1.2 to as high as 27.5 per cent. As we all know, there is a wide difference in melting losses, but the percentages reported seem to be questionable.

Table V shows the total number of pounds of good and bad castings made by the 10 foundries having complete records of their work. It also shows the percentages of good and bad castings made. These percentages are based on the total pounds of castings made.

The question, "Do you prefer to employ practical men or college graduates as teachers?" was answered by 34 schools. Practical men were preferred by 23, college graduates with practical foundry experience by eight and college graduates by three.

The question is often asked, "Does the technical school give a young man a training equivalent with that of an apprenticeship in a manufacturing plant?" It does not, but it can give him something which will be a valuable substitute. Take the foundry course, for example. Table I shows that the time allowed for such work varies in the respective schools from 20 to 144 hours. On the basis of an 8-hour day the

Table V

School number	Total castings	Good castings	Bad castings	Per cent Good	Per cent Bad
3.....	45,000	30,000	15,000	66.6	33.4
5.....	48,000	37,000	11,000	77.0	23.0
8.....	28,025	25,027	2,998	89.3	10.7
9.....	23,200	22,200	1,000	95.7	4.3
15.....	30,240	22,680	7,560	75.0	25.0
17.....	65,255	62,139	3,116	95.2	4.8
18.....	35,404	33,431	1,973	94.4	5.6
22.....	4,622	4,284	338	92.7	7.3
25.....	15,000	13,800	1,200	92.0	8.0
28.....	5,000	4,000	1,000	80.0	20.0

maximum time would amount to but 18 working days service. This time will seem to the practical foundry man as far too short, and to this we all agree, but it must be remembered that a curriculum of four years, including as it does those subjects fundamentally important to engineering, is in itself too short for any man to master these subjects thoroughly. However he should acquire a working knowledge of the subjects, and in addition a mental control which will enable him to think things out to their logical conclusions and in time, to originate and develop for himself.

Time for Courses Is Limited

Because of the fact that it is difficult to greatly increase the school time devoted to the mechanical processes, it is necessary to plan every shop assignment so that it will teach its own lesson. Speed is sacrificed to carefulness and accuracy, and the repetition of processes merely to acquire skill of hand is sacrificed to variety. That is to say—when a process has been done intelligently and acceptably well, a new one is substituted bringing into effect entirely new educational ideas. By this method every minute may be made to count for the most in an educational way.

The importance now attaching to the foundry business brings to the schools a new problem—that of extending the work materially and including those engineering features that make for economic production. In connection with the practical work on the foundry floor, such as molding, core making

and pouring, there is need of instruction and research along engineering lines such as planning and managing foundries, cupola studies by the aid of chemical analyses, economic production by the aid of molding machines, selection of cores and core sands and other problems of equal importance that are presenting themselves for solution. These advanced lines where established will probably have to be taken as special or optional courses by the junior and senior students.

The foundry problem is yet to be solved. The schools are beginning to work on it and developments are sure to come. Much more will be accomplished in this line when the foundries of the country appreciate the fact that the technical schools can and probably will send out men each year who are fundamentally qualified to assist them in their problems of reconstruction. What everybody needs just at this stage of the game is an exhibition of co-operative spirit. The foundries can do a much needed work in an advisory capacity, by keeping in touch with the work that is being done in these institutions and making suggestions for the drafting of courses and the administering of the work. On the other hand those men who teach the subject, in most cases, are men of considerable practical experience and would undoubtedly welcome any suggestions coming from reliable sources.

Report of Committee on Industrial Education and Training of Apprentices

During the time since the 1920 convention of this association, your Committee on Industrial Education and Training of Apprentices has been active in securing information from similar bodies regarding their programs of apprentice training.

While practically all manufacturers agree that there is a great need to revive thorough apprentice training, yet very few individual firms have made any attempt to carry on complete apprentice training in their plants. Of the various industries where it is generally recognized that thoroughly trained apprentices are needed, the foundry industry is trailing behind because of lack of organized effort to take advantage of what training facilities are offered by the states and federal government. Very few foundries are so located that, if an effort was made to find out the possibilities of assistance available, but what means could be found to give apprentices part time education in the schools.

The Employer's Responsibility

Many foundry men complain that they cannot get the type of boy they wish to enter as apprentices. The foundryman is, as a rule, at fault in this matter. It seems that certain changes must be made in foundries before boys can be induced to learn the molding trade. It is not so much a question of wages as it is a question of what can a foundryman offer a boy. In the first place, the average boy is surprisingly ignorant of what a foundry holds for him in the way of opportunities. The supervisor of apprenticeship of Wisconsin found through a questionnaire sent to all apprentices that 85 per cent. of them knew absolutely nothing of the working conditions and the exact nature of the work before they became apprentices. This means that the boys must be reached in the part time schools with lectures and descriptive literature, which they can take home

with them and where the parents also may see it. It was found that 50 per cent of the boys apprenticed in Wisconsin were induced to learn a trade because the parents insisted on it. There are still plenty of desirable boys ready to sacrifice wages for training if they can be reached and then shown that the trade is worth learning. Boys from local schools should be invited to come and look things over in the shop.

Too many boys who enter a foundry soon quit unless an interest is taken in them. At the start they must be taken aside and thoroughly informed of all they are expected to do and then be put through a prescribed course of practical training. A strict adherence to the policy of giving a diversified class of work to do and a bonus at the end of an apprenticeship is the surest means of keeping apprentices on the job. An important reason why the right kind of boy has steered clear of the foundry and in which the employer is at fault, is the usual dirty conditions existing in most foundries. Employers must clean up their foundries and make them more attractive places in which to work. By so doing and then gradually inducing a higher type of boy to replace the present type of foundry worker, progress can be made.

Many employers flatter themselves that they are too busy to assume any responsibility for apprentice training and defer their attention to suit their needs. Also many employers have no apprentices, depending upon "the market" for their labor supply. They seek the men whom some one else has trained. This method is akin to stealing from him another employer, who, in turn, will do likewise.

If one will but study the history of juvenile labor, he will find that old-time laws laid emphasis on the obligation of the master to the young apprentice. It was a two-fold responsibility; the master was answerable for the health and moral development of the lad, while in his employment, and for his service to the state and career as an adult, since this service and his career depended on his physical, moral and technical training as a boy.

The interest of the employer in his apprentices will foster and develop a spirit of loyalty and integrity, possible in no other

way. It will do much to dissipate the feeling that the only interest an employer has in his workers is the money gained from their labor. It will develop a wholesome spirit of productive rivalry and build up a type of efficiency which cannot be obtained otherwise.

This spirit of responsibility on the part of the employer is greatly lacking in the foundry industry and must be realized before real apprenticeship training is a common occurrence in the industry. Foundrymen of the country have not taken advantage of the training facilities which are offered by the states and Federal government, and until such assistance is used and definite apprentice instruction is undertaken in the shops, conditions will remain as they are at present and the supply of trained men to act as foremen and assistant foremen will be very limited.

To gain some idea of the interest of the foundrymen in apprentice training, your committee sent to each member of the Association a questionnaire on this subject. A very small percentage of the questionnaires were returned, which in itself indicates a lack of constructive interest. The answers to the questionnaires returned were tabulated and the data given below:

Number of questionnaires sent out—1200
Number of questionnaires returned—38; about 3 per cent returned

Question No. 1—Do you have apprentices in your foundry? Twenty-six replied "yes"; 11 replied "no."

Question No. 2—If you have apprentices, what kind of training do you give them? Five plants had special training department and supervisors of apprentices and outlined apprentice courses of three or four years duration. Three plants had outlined three or four year courses where apprentices were under general supervision of foremen and journeymen molders. Eighteen plants had apprentices with no regular outlined course. Apprentices received some aid from foremen and molders and in most cases were put on piece work after short time experience.

Question No. 3—If you do not have any apprentices would you like to have them? Ten replied "yes." One replied that the shop had no need for apprentices as such but that the shop trained machine molders.

Question No. 4—Do you believe Foundries should train apprentices? All replied advocating apprentice training.

Question No. 5—If training is advocated how should apprentices be trained?

Plant 1. Thorough course in their own trade with enough time in related departments to familiarize with such work.

Plant 2. Three year course.

Plant 3. Three year course and enroll in correspondence course.

Plants 4 and 5. In a group with special instructor.

Plant 6. Actual work supplemented by school training.

Plant 7. Vestibule School.

Plant 8. Preliminary training in Vestibule School or in local Manual Training School.

Plant 9. By competent instructor who realizes important relation between quality and quantity.

Plant 10. Class work and practical experience.

Plant 11. Supervised training work.

Plant 12. Practical shop work with encouragement to go to high school and college.

Plant 13. By foreman.

Plants 14 and 15. By special instructor.

Plants 16, 17, 21, 23. Practical work under skilled workmen.

Plants 25 and 26. Practical and Theoretical training.

Plant 29. Technical course in combination with shop practice.

Plant 33. Day or night courses in Manual Training Schools.

Plant 35. All round practical training.

Plant 36. Scheduled shop training, class work in addition to continuation school and designed to cover technicalities of trade.

Plant 37. Vestibule school with part time class work.

Plant 38. Trained with competent molders under the supervision of the foremen.

Question No. 6—Do you recommend foremen training? Twenty-four advocated foremen training; 1 replied "no." Character of foreman training advocated:

Plant 1. Recommends foremen training in organizations too large for personal contact with executives.

Plant 3. By permitting attendance at conventions and visiting other foundries and by supplying foundry literature.

Plant 5. By foremen's conferences for the purposes of discussing and pointing out duties of foremen and assistants.

Plant 6. By taking foreman's course in local college.

Plant 7. Any kind that will result in obtaining closer understanding, co-operation and co-ordination of various departments, by heads of departments following get together luncheons.

Plant 8. By holding foremen's meetings, where talks are given by outside speakers and local executives.

Plant 9. By supplying books and Y. M. C. A. Foremanship courses.

Plant 10. By attendance foremen training classes of University Extension courses.

Plant 21. Train by instruction of graduate technical engineers who also have had practical experience in foundry.

Plant 34. By Y. M. C. A. courses.

Plant 36. We consider the best foreman training to consist in an adequate apprenticeship system training which will produce a sufficient number of trained mechanics, from whom foreman may be chosen.

Plant 37. Foremen meetings of educational type.

Question No. 7—Do you in your plant attempt to train foremen? Sixteen replied "yes"; 16 replied "no" and no statements were received from 6.

Question No. 8—Do you attempt to co-operate with the public schools in training apprentices, workmen, or foremen, and if so how? Eleven replied "yes"; 14 replied "no" and no statements were received from 12.

Plant 6. Sends apprentices part time to technical high school.

Plant 7. All minor apprentices attend continuation school at least one-half day per week for not less than two years of apprentice time. Time to be paid by plant.

Plant 8. Apprentices sent to local manual training school one day per week during school period.

Plant 9. By giving men scholarships to night courses and Y. M. C. A. free providing they attend 90 per cent of classes and pass exams.

Plant 10. Foremen take University Extension courses.

Plant 13. Co-operative course with local school, apprentices work for five-week periods in shop then five weeks in school.

Plant 14. Send apprentices to local school for night instruction in related subjects such as drawing.

Plant 22. Through night schools for vocational training.

Plant 36. Continuation part time classes.

Question No. 9—General Recommendations.

Plant 5. Issues pamphlet describing their outlined apprentice course. Each graduate apprentice is awarded a $75.00 cash bonus and a suitable certificate of apprenticeship on which is inscribed the length and character of his apprenticeship and the successfully completed classroom studies. Compensation is graded from twenty-two cents per hour for the first half year to thirty-four cents per hour for the third whole year. The practical training in the foundry concerns itself with the knowledge and mixing of molding sands, the making and baking of cores, molding operations, by machine and hand with other foundry processes. All molder apprentices receive classroom instruction in arithmetic, algebra, plane geometry and mensuration, chemistry of foundry materials, mechanical drawing, business English and industrial history.

Plant 7. Advocates careful selection of apprentice instructor, for one whose chief qualities are insistence on good work, capacity for instructing and ability to get and hold interest of apprentices.

Plant 10. More attention should be given to training foundry apprentices in cupola practice, core making and all branches of the trade. Too many specialty men have been turned out. Today there is a shortage of all round mechanics.

Plant 11. Insist on good character and give all round training.

Plant 13. Believes it is necessary to train apprentices for if we do not, we will be suffering from the want of good men in the foundry in a few years.

Plant 14. Finds it very difficult to secure competent foundry apprentices who will study the art of good molding and melting practice. Boys who would make good molders are urged to secure cleaner and better positions.

Plant 16. Endeavor to make working conditions such as to attract young men with intelligence and fair education.

Plant 24. Give the boy a good chance and keep giving him different classes of work and do not keep him laboring too long. Boys starting on apprentice work have too often been disgusted by being

kept on laboring work too long and by seeing that no effort is made to help them get all round experience.

Plant 36. Given tradition of excellent workmanship in a plant, adequate training resolves into three elements. (1) Direct supervision. (2) Instruction in manual technique of the trade. (3) Instruction in related technique of the trade.

Plant 37. Have prepared an analysis of the trade for guidance of apprentice supervisors.

More than 20 of the states have enacted legislation compelling boys and girls to attend school part-time after entering upon employment. This movement is spreading and should receive the active support of every foundryman interested in seeing an effective apprenticeship system developed. Educators generally agree that the part-time plan properly worked out is the most effective way of teaching a trade. The apprentice learns how and why in school and develops skill by application in the shop.

The federal government and the several states have made large sums available for training and employing apprentice instructors. These persons may not only teach apprentice groups but follow the individuals into the shops of the employers to help maintain satisfactory teaching and learning conditions there. Wisconsin has taken the lead among the states in recognizing this social responsibility but it is hoped that other states will follow her lead.

The Wisconsin Law

The State of Wisconsin enacted an apprenticeship law in 1911 and amended it in 1915. This law provides that all minors who receive instruction as a part of their consideration of their employment shall be indentured. All such indentures must be approved by the State Industrial Commission and can be enforced against both the employer and the apprentice. Geo. P. Hambrecht, chairman of the Industrial Commission says, regarding this law: "'In administering the apprenticeship law the commission has at all times sought the co-operation of employers and employees. As early as 1915 it organized a general apprenticeship committee, composed of representative employers, employees and educators. In the past two years about 1000 new indentures have been entered into between apprentices and employers, though this was the period of war reconstruc-

tion. The Wisconsin apprenticeship law has stood the test of the experimental period. A Wisconsin apprenticeship is coming to be recognized by employers throughout the country as a guarantee of a truly skilled mechanic and was so regarded by the United States government during the war period.

"This law, however, is only a recent enactment and in consequence is yet little known among parents, boys, or employers. Apprenticeship is not yet by any means as general in the state as it should be. The most important work to be done in the immediate future is publicity and more publicity. The directors of the continuation schools are already quite generally boosters for apprenticeship, but assistance must be secured from the public school teachers, so that they may act as advisors to boys and girls to lead them into some productive trade instead of allowing them to enter some 'dead end' occupation without a future."

C. B. CONNELLEY, *Chairman*
C. B. AUEL
J. B. CHALMERS
G. B. KOCH
J. N. STEELE
J. D. WISE
R. E. KENNEDY, *Secretary*

Discussion

CHAIRMAN G. H. CLAMER: The training of apprentices is a vital issue with us at this time. In entertaining Messrs. Stubbs and Firth, the president and past president of the Institution of British Foundrymen, in New York a few weeks ago, this subject was discussed and the different conditions existing in the foundries of this country were compared with those abroad, particularly in England. In England, as Dean Connelly has stated, the business passes on from father to son, and the foundryman has to deal with other Englishmen—all of one nationality. They understand each other and speak the same language. In this country our common labor, particularly,

is drawn from many nationalities; they do not feel the same as we do; they have not the same interests at heart. We have a problem of maintaining our present standing and prestige among the foundrymen of the world by training the kind of men that we have to handle.

It was brought out at that meeting that particularly the lower class of foreigners coming here are willing to work, when they come here, as laborers. They get good pay and are thrifty. Their children are sent to our schools. But, instead of wanting to follow in the footsteps of their fathers and become laborers, doing the heavy work, they seek positions where the work is not so hard. It really is surprising, in a few years, with the American advantages, what the foreigners are able to do. We have two problems before us; one is the supply of common labor and the other is the supply of skilled labor. They are real problems and will have to be given enthusiastic, careful and continued consideration.

MR. BANCROFT: I want to commend Dean Connelly on the remarks he made. If the foundrymen of this country do not do something to train some of the young men, we are going to be in bad shape in the industry in a short time. Many young men who are trying to produce good work are very much discouraged. Instead of receiving information they are being given misinformation from some of the older men. If they were getting more help from the foremen, it would help considerably, but, as Dr. Connelly says, the foremen are pretty busy and haven't the time to give. This problem will have to be solved sooner or later.

Prevention of Industrial Waste

By L. W. WALLACE, Washington, D. C.

When the lessons of the war had been counted and the new era of progress started there was one great problem that all industries throughout the world faced,—prevention of waste. The first nation to solve that problem will have a tremendous start in the race for industrial supremacy. Seeing this, as a result of careful studies at home and abroad, Herbert Hoover laid the problem before the Executive Board of the newly organized Federated American Engineering Societies, and authority was at once granted to organize a committee to investigate waste in American industry.

To be of value to American business the report of this investigation naturally had to be prepared in the shortest space of time consistent with thoroughness sufficient to make the work representative. The ultimate object of this investigation was prevention of waste, but first the causes of waste had to be learned and recorded. Early in January 1921 the Committee met in New York to outline the policies to be pursued in making the investigation. The essence of the plan adopted was to gather as quickly as possible such information as might be used to stimulate action and to lay the foundation for other studies. It was believed that a limited yet careful study would not impair the value of the facts disclosed nor the significance of the recommendations based upon the same. In short, the chief purpose of the work was to make a quick investigation of the conditions and of their trend, with the idea in mind of making a more detailed and exhaustive investigation afterwards. Within less than five months the Committee completed its study and laid a summary of its findings before the Executive Board of the American Engineering Council on June 3, 1921. This material has since been edited and printed in book form, together with definite recommendations as to how the findings of the Committee could be used as a basis for constructive work.

The value of this work and its concrete objectives, many of which are being followed out in the manner recommended

by the Committee, are probably best explained in the foreword to the printed book. This foreword was written by Mr. Hoover and is as follows:

"This reconnaissance report on waste in industry is the result of five months of intensive study, carefully planned and rapidly executed. A part of its value lies in the speed with which the work has been done, and the promptness with which it presents definite lines for future action. It reveals facts which may serve as a foundation for an advance in American industry. It has a special message for government officials, financial, industrial and commercial leaders, labor organizations, economists, engineers and research groups, the general public and the press.

"We have probably the highest ingenuity and efficiency in the operation of our industries of any nation. Yet our industrial machine is far from perfect. The wastes of unemployment during depressions; from speculation and over-production in booms; from labor turnover; from labor conflicts; from intermittent failure of transportation of supplies of fuel and power; from excessive seasonal operation; from lack of standardization; from loss in our processes and materials—all combine to represent a huge deduction from the goods and services that we might all enjoy if we could do a better job of it."

The original plan contemplated ten investigations in the field including transportation and coal mining. Six have been completed. They include building trades, men's ready-made clothing, boots and shoes, printing, metal trades and textile manufacturing. In addition to these specific fields, studies on seven general reports of a statistical character were prepared, each of them dealing with some aspect of industrial waste or its elimination on an extensive, nation-wide basis.

Leading Factors in Prevention of Waste

In the ten outstanding features of the report may be found the leading factors in prevention of waste. These findings show:

First. There is apparent lack of a common terminology of management and personnel factors. This lack is the cause of much confusion. To one group the word management means one thing; to another an entirely different meaning is conveyed. The public is confused by a lack of common knowledge of the meaning of industrial and management terms.

There is a great need for constructive work in defining such terms. The establishment of a common terminology and a concrete definition of industrial words and phrases would lead to the elimination of much misunderstanding throughout industry.

Second. Another significant need is the creation of standard units of measurements for the various factors of management. This applies particularly to the factors of individual and group performance. It is true that there are some factors of management for which it would be exceedingly difficult if not almost impossible to create and to apply units of measurements, yet there are many for which it can be done. It is also true that some progress has been made in the way of establishing standards for gauging individual and group performance. But in the main the practice is limited and is based upon inadequate data and faulty premises. It has not been approached in as thorough and as scientific a manner as its importance would justify. In a very large degree the whole system of wage payment is faulty because it is not based upon facts scientifically arrived at; and further, in a great degree definite standards of performance are not known.

Third. In the realm of industry there is no agency that can furnish complete, timely and authoritative, data upon the various functions of industry and unless such data is available no rational remedy can be evolved for solving the many industrial and economic problems now confronting us. On so vital a thing as unemployment there is no central bureau of information; the facts have to be pieced together, so to speak. This indicates the need for a permanent clearing house on unemployment. It should be the function of such a bureau to make an exhaustive analysis of the many factors connected with unemployment so that such information would at all times be available. Further, it should study the causes, analyze the remedies applied, and make recommendations as to how to alleviate unemployment in emergencies, and, finally, suggest what might be done to bring about a more permanent or stable employment cycle. The advantages to accrue are large in social, political, industrial and economic values. For after all, much

of the unrest, suspicion and disturbance among workers results from the subconscious and conscious fear of unemployment. This is made apparent from the fact that the so called seasonal industries, as clothing and building, have had the greatest amount of labor disturbance.

In the matter of strikes and lockouts there is no central source of authoritative information.

It is the belief of many that there should be central bureaus of information concerning many phases of industry, as the quantity of raw and finished materials, the cost of basic raw materials and the like. Until such bureaus are established industry as a whole will continue to be wasteful, because without a knowledge of the facts, rational measures of correction cannot be evolved.

Fourth. There is a real need for some form of co-operation that will safeguard the interests of the public, yet permit of a free exchange of information between the various organizations of a given industry and between interdependent industries. Many plants of a given industry have developed and perfected important and economical management policies and practices which are not known to the industry in general. If they were known in detail by the industry as such, better conditions would prevail. It is also true that there is a great deal of duplication in the expenditure of money for research and other purposes, because of the lack of an interchange of information. Of course, it is recognized that a certain amount of such duplication is inevitable for purely commercial reasons, yet there is a large area of mutual interest.

At the present time there is very little co-operation, and co-ordination and exchange of information between interdependent industries. The manufacturer of clothing uses the material produced by the textile manufacturer. Likewise, the users of paper take the product of the papermaker. Very naturally there is a close community of interest between the designer and the retailer of ready-made clothing. Yet these two important elements of the clothing industry have not until

recently taken any steps towards co-operation and co-ordination with reference to styles.

Fifth. It appears, from the available data, that the amount of waste from the general run of strikes, through the loss of wages and curtailment of production, is less than commonly thought. This of course does not refer to the losses that occur through such strikes as are all inclusive, such as real or threatened strikes on the railroads or in the steel industry.

That the apparent losses are less than commonly thought is in part due to the fact that the general run of strikes occur in seasonal industries. Thus, the total production for a given season may be and is often realized by prolonging the period of activity. For instance, more coal was mined in 1910 than in 1911, although the former year witnessed many protracted strikes involving large numbers of employees. In 1912, with 47 per cent of the entire labor force out on strike and with an average loss per man of 40 days, the output of coal per man, per day and per year, was more than 1911. There was also six days more employment than in 1911, a year which was relatively strikeless. The total production was also more.

In addition to the direct losses through wages and curtailed production, there are, of course, indirect losses, but no means is available to determine the extent of such losses. The information obtainable is inadequate on any phase of the problem. There is no agency that has the responsibility and authority to collect the information requisite for a complete and authoritative analysis.

Sixth. It is a fair statement that for the country as a whole there are no adequate functioning bodies for the adjustment of industrial disputes, and hence, the checking of industrial waste that results therefrom. There are almost as many varieties of legal machinery for adjusting labor disputes as there are states. Seven states have laws for local arbitration, but no permanent agency to execute them. Two states legalize permanent district or county boards established by private parties. Nine states provide for arbitration or conciliation by the State Commissioner of Labor or some other state

official. In 27 states there are laws creating a special State Board or Commission for the settlement of labor disputes. In Kansas, a court of industrial relations has been established with very broad powers. Nine states make provision for local boards as well as for bodies with state-wide powers.

A recent examination shows that machinery for the adjustment of industrial disputes is active in 11 states, that is, it functions with more or less success; that it is inactive in five states, and dormant in 19. That there is a real need for some adequate agency to function in the realm of labor disputes is apparent.

Seventh. A lack of rational standardization of methods, practices, policies, and designs is a prominent cause for industrial waste. A great advance and refinement can be made towards standardization without in any way limiting individual ingenuity or unnecessarily curtailing the reasonable desires of any person. The possibilities for standardization occur in almost every phase of industry.

A prominent locomotive building company was able to build 163 standard designed locomotives in five weeks, while it was able to produce only 104 locomotives of special design in the same period. Losses in production due to lack of standardization arise in every industry. You desire to build a home, an office or a factory building. You ask for designs and bids; six, eight or ten contractors submit plans, specifications and bills of materials. The contract is let to the lowest bidder; but in his price is included not only the cost to him of making the plans and specifications for the job, but also a percentage to cover the cost of all other jobs on which he has placed a bid and has not secured the order, or else a percentage to cover the cost of the seven or eight other bidders, there sometimes being an agreement among the bidders that this be done. In certain cities there are certain bidders who always bid high. They do not want the contract. They make their living by the commissions collected on their useless figures.

With the foregoing information in hand as to some of the major things to be done to prevent waste, the committee enu-

merated some of the particular responsibilities of management, of labor and of other groups.

Management Responsibility

First. For the most part, planning and control of production has not penetrated most of American industry, but should be adopted as fundamentals of good management, because conscious production control tends to eliminate waste by shortening the total time of production. It ensures the delivery of material where needed, whether it be material in process or finished product ready for shipment. Material schedules should be installed and used. These are a means to reduce idleness of material, of the workers who are going to operate upon it, and of the machines and tools forming the equipment for the processes which it is to enter.

Second. The practice of cancellation of orders between manufacturer and mill and between manufacturer and customer should be eliminated and there should be a curtailment of the privilege of returning goods ordered and received. Such cancellations and return practices are vicious and directly hinder stabilization.

Third. In many factories, losses of labor and material in spoiled and defective work are unwarrantedly high because of inadequate inspection. The aggregate annual wastage of human effort and goods from this cause is very great.

Fourth. Uniform cost accounting systems for finding costs should be established in each American industry. In controlling production and in judging fairly and accurately when and where progress and improvement are being made, the lack of a good cost control system is necessarily a source of much waste.

Fifth. Methods of wage payment should be adopted, equitable and just in their basis, ensuring a proper relationship between effort put forth and results achieved by all who participate in the enterprise.

Two leading facts should be grasped: Special wage methods are almost wholly futile in the absence of standardization and system in the work; production standards and proper con-

trol of work will, without any special wage method accomplish a large part of the desired result.

A danger lies in assuming that clever devices can take the place of good management. The most important function of a wage payment method from the production standpoint, is to oblige management to do its duty.

Sixth. Management has a definite responsibility in selecting, up-grading and maintaining personnel. Experience indicates that the best results can be obtained when employment and personnel direction develop a sense of mutual interest in production on the part of management and workers, individually and collectively, in creation, in craftsmanship and in the contribution of their experience and knowledge to the productive processes. "Industrial relations" to be effective should be closely allied to production and concern themselves with educating the workman in the science of process, recording his accomplishment and enabling him to become conscious of the relationship of his work to the whole.

Such industrial education and training as has been conducted by certain leading manufacturers has obtained beneficial results, and it is believed that further developments along these lines is desirable.

Seventh. Industrial research should be consistently carried on both in the individual plant and by associations. The need for knowledge obtained by such research is manifest in every industry studied. Although comparatively new in this country, the success of research laboratories conducted by a few large industrial firms and trade associations is well known.

Labor Responsibility

Eighth. In discharging its responsibility for eliminating waste in industry, labor should co-operate to increase production. It should appreciate the value of facts and discount mere opinions. All concerned need to remember that science is an ally and not an enemy, and that no policy can be soundly based which ignores economic principles. Ignorance of principles lies at the root of most of labor's restriction of output. Labor should co-operate to prepare for and even demand the determination

of and use of performance standards. It is to the worker's interest rather than to his detriment that his services should not only be efficient but definitely recorded and evaluated.

Labor should change its rules regarding restrictions of output, unreasonable jurisdictional classification and wasteful methods of work, thereby removing large sources of waste.

Government Responsibility

Ninth. A nation-wide program of industrial standardization should be encouraged by the government in co-operation with industry. In the stabilization of design of product, methods of procedure and number of models, there rests a large opportunity for the reduction of waste.

Results of Publication of Report on Waste

The report on waste in industry has stimulated a great deal of action. Many industrial organizations were quick to grasp the importance of the subject and adopt measures that were suggested. Scientific and trade organizations have made special studies for the prevention of waste in the branch of industry that they are specially interested in. Educational institutions have made waste a subject of special study. Several branches of the department of commerce have made special studies of waste and recommended means for its prevention to the industries.

The government, for instance, after consultation with interested representatives of the respective industries has recommended standards in paving brick, in lumber and other commodities. A forum now working in co-operation with the department of commerce aims to establish means of giving publicity to the internal affairs, tonnage, price conditions, etc., of construction material industries. The rights and duties of trade associations to their constituents and to the public are in process of being defined by the department and written into law by congress in a way that will bring out valuable information and prevent much waste. The scope of the President's unemployment conference has been extended until the resultant study promises to do much to eliminate seasonal and cyclical depres-

sions in business and unemployment. A joint conference on constructions contract forms has been called and is engaged in recommending standardized contract forms for various industries, the railway form is at present under consideration. These are but a few examples of the fields into which the proposal to prevent waste has extended. The field for the prevention of waste is practically infinite and its reward is great.

We have not the time to further discuss these matters, we wish to remind you, however, that a large task is before us. Large in its inherent economic magnitude—large in its human aspects,—large in its political and moral possibilities. If this is to be a prosperous nation, a nation of happy people; a nation politically sound and stable; a nation of good morals and high ideals—the enormous waste now occurring through poor management, arbitrary labor and public indifference and connivance must be prevented. In its prevention everyone has a responsibility and everyone has an opportunity.

Cycles of Depression and Their Prevention

By Ernest F. DuBrul, Cincinnati

This subject, as listed on the program, is much in the nature of a newspaper headline, whose main function is to attract attention to the story and not to tell the story itself. It is much too complex a subject to attempt to treat in the short time that can be given a paper on a full program. Therefore a bare outline is all that can be offered, and this is done in the hope of stimulating interest in a subject of the utmost importance to every business man.

Depressions are of very keen interest to everyone, because every element of our industrial system is affected by them. The largest element, in number, is the farming element, and nearly as large, is the wage earning element. When a depression is at its worst, there is great despondency all over the country, and when it is over, many who have been set back by it are left with a very dull outlook indeed. To the wage earners, a depression brings the most suffering. Jobs are scarce and wages are low. If lucky enough to have jobs, some men are perhaps over driven when they are at work. If without a job the haunting fear of poverty gnaws at their souls. What wonder then, that in times of depression the wage earner's troubles make him very receptive to every promise of a glib tongued radical who pictures a golden future of ease and comfort? Farmers and business men face losses, not only of paper profits, but of real wealth previously accumulated. Many of them go down in failure, never to rise again in the financial scale to a position of independence. What wonder that they, too, give sympathetic ear to political quacks who, with promises of cheap money and cheap credit would make these men believe that their troubles are to be easily ended, if only the quack is put in the political saddle?

Because the prevention of depressions would be of tremendous benefit to millions of our people, this subject is well worth consideration by everyone.

Everyone recognizes a depression as being an evil, a condition of business ill-health—a sort of economic disease—and as in cases of bodily disease all desire both cure and prevention. No modern physician attempts to merely treat symptoms of ill health. Medical progress has shown that the physician must get down to the real cause of a disease before he can intelligently treat it. As scientific medical research discloses the causes of disease, it becomes more and more apparent that the physician's best efforts lie in prevention, rather than cure. Yet no matter how much the doctors may learn about a disease, its causes, its cure, and its prevention, their knowledge will be of little help unless and until it becomes spread among the people. The patient or the potential victim of disease must play his part in the cure, and more so in the prevention of diseases of the human body.

So too with the economic disease of industrial depressions. Human beings of every rank and walk in life are both causes and victims of these depressions, and neither cure nor prevention can be expected until the mass recognizes the causes and co-operate in prevention. As a mass, humanity does not yet know enough about the causes to take preventive measures. Nor does the average business man seem to care enough about the subject to get down to hard study, and to keep his own house in order. Here and there a few men have been doing their utmost to consciously keep their own businesses sound, in the light of information so far available. But most business men seem to prefer to let things drift, and then they want to blame the Federal Reserve Bank, or a Buyers' Strike, or the Labor Unions, or sun spots, or anyone or anything but themselves for the losses they and their employees suffer.

Just as diseases of the body are personal to the individual, so financial disease is personal to individual concerns. A community is weakened in which many persons are afflicted with typhoid, yellow fever, or hookworm, because the sick not only cannot look after themselves, but they require attention from

the healthy. So in business, the concerns that are individually unhealthy are a drain on the community because the healthy are deprived of a market that would otherwise be offered by those who have fallen victims to financial or commercial disease.

Business men, as a mass, have not yet learned that the business structure of the whole world is essentially one co-ordinated, co-operative machine for the supply of human wants. Too many business men,—and politicians,—look upon business as a species of warfare—of a struggle without mercy in which the battle belongs of right to the strongest and in which rules for fair play are considered mere interference with the necessary conduct of the combatants. Such men have not received the broader vision that all business is co-operative and constructive, not combative and destructive. True, each one of us must find for himself the place in the system where he can best function. No superman can tell us where that place is—in spite of the Socialist's dream to the contrary. As long as society is organized under the principle of individual liberty, we must each run our own jobs, and do that in the light of the best knowledge available.

What Causes Depressions?

The fundamental cause of depressions is that too many business executives are woefully—perhaps wilfully-ignorant of some very important phases of their jobs as managers. Too few people are prepared to challenge the complacency of management, and its persistence in avoidable ignorance. Depressions are business phenomena. Business is a purely human activity, and therefore depressions caused by human beings are not by acts of God, sunspots, or any other extraneous force apart from business men themselves.

Which element in business is most responsible? How about the investor? In big business, the investor has precious little to say about the conduct of the business that is using his capital. Is it the production department? Its staff produce or not as they get orders to act, from a superior authority. Is it the sales force? They can't squeeze the life blood of orders out of a dead market. There then remains only one other element, the one that holds the final authority, the entrepreneur ele-

ment as represented by the management, the element in short, that dictates the policy of a business.

Study of Statistics Important

Depressions are ultimately due to maladjustment between supply and demand—and these maladjustments occur because those responsible for supply know too little about either supply or demand to be able to make the adjustment that is needed. Demand is the fickle mistress whose behests must be obeyed. So that those responsible for supply should know as much as possible about the course of demand in order to make the necessary adjustments. But what do they know? How many know anything about demand in general for their own specific products, except as they meet it in their own business? How many foundry men have really studied the course of the pig iron market for which they have had charts and statistics for years past? How many of them know that for years past the discount rate of 4-6 months commercial paper has predicted the course of pig iron prices and production about 5 months in advance, with uncanny accuracy? How many blast furnace men knew this and if they did, how many tried to spread their knowledge to others so that it would save the iron business from the losses of depression? How many foundrymen have known that a statistical service could be organized among them that would indicate far in advance when the blast furnace could start in anticipation of actual melting of iron for castings? If this were done, there would be less shortage of iron and less consequent skyrocketing of prices at the peak of demand. A complete statistical compilation of new orders, cancellations and suspensions, production and shipments, stocks on hand and unfilled orders by grades would give the foundry iron producers a wonderful picture of the state of supply and demand in that business. But not all producers will report those figures to their own Association. Those figures would be wonderfully helpful to the producers themselves if they were published where all buyers could use them. In such cases public comment would be made on the significance of different phases. Buyers and sellers alike would be able to run their businesses more intelligently and the furnaces would consequently have

much more regular operation than now. But when will the furnaces give out the complete figures? When will the furnace men all realize that it is against their interest to overload buyers with high priced pig iron? And when will all foundrymen get sense enough to stay out of a runaway iron market and not fall for the iron salesman's bunk talk of why prices can never come down again? When will furnace men cease building more furnaces than the country ought to have? I guess it will be when the foundrymen learn that it is dangerous to speculate on iron. When both of these elements have learned those little lessons, probably other business men will have learned theirs and then depressions will be prevented, but hardly before.

Management Should be Able to Forecast Future Supply and Demand

Management must learn such lessons or society may make the foolish attempt to manage things by collective action. Enough dissatisfaction now exists without increasing it by supine indifference on the part of management. It will not do to say that these things can't be helped. They can be helped to a great extent. True, it would be a wonderfully superior world, if every change in human desire could be foreseen and fully discounted. But it is precisely the main job of management to forecast the future just as well as possible. On that job, management has been rather a rank failure in too many cases. The sooner the failure is recognized and steps taken for improvement, the better it will be for business in every way. Intelligent estimating is sure to be an improvement over blind guessing.

Every industry can have effective means of estimating supply and demand. But ignorantly selfish management can neither grasp its value nor use it intelligently. Supply and demand can be gaged only by cooperative study, statistical compilation and interpretation of the various cyclical movements as they develop in each industry. This takes enlightened selfishness to appreciate and accomplish. Few managers would as yet know how to intelligently guide their policies, even if the statistics were available in their own fields. They need educating,

and many need the first requisite, a willingness to learn. Few managers as yet realize that study of cyclical movements in interdependent industries well repays the time and money spent on the study. It is just because they are not enlightened that they refuse to give the slight cooperative effort needed to collect the information and to learn its significance to them in their own businesses. Without it they can only proceed in ignorance of facts. As a consequence of ignorance we have the losses caused by over-stocking with high priced material or product in the face of a falling demand.

Present Available Data Not Used Enough

Of course, gathering information without using it would be a childish waste of effort and money. There is a lot to be learned about the significance of different phases of business cycles—how they develop and why, what things to do and what not to do in different stages of a cycle. Yet this knowledge is not difficult to acquire. Practical business men with fundamental training in economic theory are not very plentiful, it is true. But practical foundrymen with a training in chemistry were not very plentiful either, a generation ago. There seem to have been very few in the cast iron pipe business during the nineties. But foundrymen got to know the application of chemistry to their business, and some business men are getting to know the application of economics to theirs. Consulting economists are becoming as recognized professionally as consulting chemists or consulting engineers of various kinds. The consulting economist who knows his work can read the business weather signs fairly well, and is getting to read them better every year. The analytical economist is learning the causes of depression and the consulting economist is advising his clients how to avoid disaster by getting out from the path of the impending avalanche. Both of them watch the development of a cycle, and by analytical statistical study of previous cycles they know the signs. Their offices are becoming well recognized as business weather bureaus. They know that over-booming breeds depression and they warn their clients and employers well in advance. The trouble even yet is that many business men who had ample warning did not believe in the signs because

their education in economic theory had been sadly neglected. They thought that the war conditions somehow had changed the fundamentals, but human nature does not change, and economic forces based on fundamental human nature worked out as always, and over-booming brought depression.

Even though business men know that over-booming at one time is sure to cause depression later, how many of them will learn to restrain their optimism and reef sail before the storm is so strong upon them that it is too late? A ship captain can now be warned by radio-phone that a storm is close at hand. What would you think of his judgment if he neglected weather reports, depending only on his own lookout, and persisted in carrying full sail till the moment the storm broke, thereby losing ship and cargo? Yet many a business captain excused his own ignorance that has been as reckless.

With the radio available, would we think a captain or ship owner competent who would not equip his vessel to at least receive reports? Do we not expect every large ship to use every means to better the weather service on the sea, to report to shore the state of weather in its own location, and have the shore stations make up weather maps from all available reports and then send back to the ship at sea their prediction for the next few hours? This is cooperation of the right kind. The same sort of thing can, and should be done in business. The more reports that are gotten, industry by industry, the better weather maps of business will be drawn, and the better will business forecasting become.

Data on Averages Misleading

Unfortunately, too many people are placing a child-like trust in average lines, drawn as composite curves, from data that has no logical connection. Averages conceal facts. We have to make different curves for different lines of business to get at true conditions in these different lines. Some precede, others lag in rise or decline of their demand. Some demands are much more constant than others. Some very important industries, particularly the metal working industries and the construction and equipment industries have much sharper peaks and longer

and deeper depressions than the food industries. A clothing industry's curve is quite different from a food industry's curve of activity. Heavy machine tools show quite different curves from light machines, and small tools show curves entirely different from either.

One who wishes to closely estimate his demand cannot depend on some general composite average curve or chart, any more than the sea captain could depend on an average curve of wind velocity. A dead calm in one place and a fifty mile hurricane in another would average 25 miles. But a ship captain in the calm and another in the hurricane belt would each have quite different problems from a third in a twenty-five mile breeze. The becalmed sailor would be mighty anxious to know when a breeze was heading his way, while the storm tossed mariner would be mighty anxious to know when the wind would die down, and they might not be very far from each other at that. In between, the captain clipping along with the good breeze would want to know whether to look for a calm or a storm, and how soon.

Cooperation in Securing Statistics Needed

The weather bureau ashore can tell them all what they want to know if enough of them report their own weather back to shore first. So, too, with weather service for business. Let enough industries report the course of demand and supply from month to month, later on from week to week, and the observers of the business weather service will be able to predict from the past what is likely to happen in different zones in the near future. By observing, and by recording, compiling and comparing observations even the currents of the air are becoming well enough known to be charted, just as are the currents of the sea. All this is done for just a small branch of business,—navigation. Why should we not do something similar for other important parts of business?

"If 'Knowledge is Power' then 'Ignorance is Weakness.'"

Why be content with the weakness of ignorance when we can have the power of knowledge, at less cost than the sums we now waste through ignorance?

To err is human—and it is precisely because so many do the wrong thing for a given time in business that we have the extremes of boom that cause depressions later. If, when the next era of prosperity develops, there are more men who have learned how and why to guide their policy sanely, if there are more men of knowledge who also have the will power to resist the temptation to extravagance and over expansion, there will be that much less wild inflation, and less over-ordering and cancellation, less over-selling and failure to deliver, less over-borrowing and failure to pay.

Over Booming Brings Depressions

Let us have more industry statistics of the right sort. Let us publish them where all may read and interpret them. Let us have more study by business men of the real workings of that Law of Supply and Demand that so many talk about and so few understand. Let us realize that Economics and Statistics are real scientific tools to be used, and not scorned by business men. Then we shall have better business, and we shall more surely reach the goal of all business. Profits must on the whole be sufficient to reward men for undertaking production. But it is not to the interest of the public that such profits be gained only in hurricane days in great enough volume to repay the business man for long periods of idleness. The risk is too great for the reward under such circumstances.

To use a phrase from the power engineers' hand book, many businesses have a bad "load factor," and besides, many of them have excessive equipment compared to their greatest peak load. This is social waste of capital. Every step that can be taken to stabilize, or regularize the load means that much less waste of capital. By reducing wasteful investment, more capital would be free to supply additional wants. As it is now, the investor hears of the big profits of boom times, but the promoter conveniently forgets to mention the losses of depression. Losses do not add to the glamor of a prospectus, but they certainly bring down returns to an average that society on the whole must pay to get its work done. If the earnings of some businesses in some years were not so big, their losses of some other years would not be so big. The big profits of

some years tempt investment in excess plant, and with a slackening of demand the excess plant competes for business on a cut-throat basis, with loss to all.

If our industries were all perfectly frank in publicity of supply and demand, cost and profit, capital investment could be made on a sane basis, and competition would better take care of the supplying of human wants at fair prices that would be steady.

The economist's abstract concept of a theoretically perfect market necessarily presupposes a fully informed market, in which all buyers and all sellers will know the exact state of the market. Then only can competition work out the fairest price. Those who, through mistaken ideas of selfish advantage, refuse to make the disclosure necessary to perfect the market, simply encourage the dreamers to devise something in the way of socialism that would surely ruin industry and society itself. Russia should be example enough for us all. Let us not live in a fool's paradise, dreaming that such things cannot happen in the United States. If business men will not see the need of getting down to prevention of industrial woes, it need not surprise us if the ill-informed voter should insist on trying his hand at the job the business man should have done. Many misguided radicals are continually egging the ignorant voter on to do that very thing.

Business efficiency has been put to its defense. It has no excuse for further delay in studying the disease and the remedy both of which have been indicated by economists for some years past. The final answer is in the hands of business men, and theirs is the final responsibility for a proper solution.

Report of the Committee on Foundry Costs

To The American Foundrymen's Association:

Your committee on Foundry costs has agreed upon the following suggestions to our membership to the end that more general and accurate knowledge of costs may result.

Meetings have been held on March 10 and April 4, 1922, both in Pittsburgh with practically full attendance.

On the first named date it was decided to confine our efforts for the present to the gray iron branch of the industry, and therefore the suggestions herewith are made with especial reference to the gray iron plant.

In the years since the American Foundrymen's Association first began to urge upon its membership the importance of cost determination and recording there has been prepared a number of plans more or less elaborate for these purposes but for various reasons none of these has been generally adopted and there still remains the task of devising some method which will appeal to the average foundryman and especially to him so situated as to not require accounting help of a high order.

In the organization controlled by such a man, the proprietor or active head is usually too fully occupied in running his plant and selling his product to devote much time to an accounting scheme which will change his method of bookkeeping, or to any set of abstract principles, no matter how sound, from which he must construct his own cost system.

What is needed at this juncture is a plan fully developed, which the head of a concern after satisfying himself of the correctness of its principles, can turn over to his existing office force and receive from them at convenient intervals data which will guide him in management and selling.

That has been the aim in compiling the accompanying forms, and it is to be hoped that their utility will appeal to the men who so far have not been reached effectively, and that

Accounts		
Classification	Accounts	Subdivisions
Rent	Rent	
	Interest on Bonds & Mortgages	
	Taxes	Federal Taxes (Except Excess Profits Tax)
		State Taxes
		Municipal Taxes
	Fire Insurance	Fire Insurance
		Use And Occupancy Insurance
	Maintenance Of Property	Repairs to Buildings
		" " Building Eqpt.
		" " Yard Eqpt.
Administration	Administrative Salaries	Officials
	Office Salaries	Auditing
		Engineering
		Purchasing
		Laboratory
		Costkeeping
		Shipping
		Storeroom
		Watchman & Janitors
	Office Expense	Printing & Stationery
		Maintce of Office Eqpt
		Laboratory Supplies
		Postage
		Telephone & Telegraph
		Travelling (Except for Selling)
	Liability Insurance	Liability Insurance
		Plant Hospital
	Replacing Defectives	Defective Work Less Scrap Value
	General Expense (Office)	Association Dues
		Donations
		Demurrage
		General Expense

FIG. 1

the terrible indictments of the average American business man by such authorities as Hurley and Hoover, regarding general lack of cost knowledge may be made less true.

The plan proposed is not new. Similar methods have been used successfully in other industries, therefore the proposition

Accounts		
CLASSIFICATION	ACCOUNTS	SUBDIVISIONS
POWER	WAGES	ENGINE ROOM WAGES
		BOILER " "
		REPAIRMEN "
	MATERIAL	FUEL
		WATER
		ENGINE ROOM SUPPLIES
		BOILER " "
		ELECTRICAL "
	MAINTENANCE OF MACHINERY	REPAIRS TO ENGINE ROOM EQPT.
		" " BOILER " "
		" " MISC. POWER "
	PURCHASED POWER	CURRENT BOUGHT
		STEAM "
METAL	METALS	CHARGE: PIG IRON USED
		SCRAP USED
		REMELT "
		ALLOYS " "
		INCOMING TRANSPTN.
		PILING
		CREDIT AT SCRAP PRICES:
		DEFECTIVE CASTINGS
		GATES, HEADS & SPRUES
		PIG BED & DROP
	MELTING LABOR	HANDLING FROM PILES TO FLOOR
		FOREMEN MELTERS
		CHARGERS & HELPERS
	MELTING MATERIALS	FUEL INCL FREIGHT & HANDLING
		FLUXES
		MISCEL SUPPLIES
	MAINTENANCE OF MELTING EQPT.	REPAIRS TO CUPOLA
		" " BLOWERS
		" " MISCEL EQPT.
		" & RENEWALS OF TOOLS

FIG. 2

is not an untried experiment. The plan has been developed with especial attention to the gray iron foundry and its problems. Flexibility has been one of the principal aims so that the organizations smaller than the average may condense and the larger ones expand the forms to cover any needs.

Accounts		
Classification	Accounts	Subdivisions
Tonnage Chgs.	Molding Materials	Sand Used Incl Transptn And Handling To Storage
		Misc Material (Plumbago, Nails Etc)
		Gas & Oil For Drying
	General Expense (Manufacturing)	
	Undistributed General Labor	
Molding	Foremen	Molding Foreman
		Clerks (Molding Dept Only)
		Office Expense
	Non Productive Labor	Moving Patterns & Flasks
		Common Labor
		Pouring Off
	Maint'ce of Molding Eqpt.	Rep To Cranes Monorail Etc.
		Rep, Ren, & Relining of Ladles
		" " Of Hand Tools
		Rep To Molding Machines
		Rep & Ren. Misc Molding Eqpt.
	Repairs To Patterns & Flasks	" " " To Std Patterns
		" " " " Flasks
	Direct Molding	Molding Time Charged To Productive Orders
Coremaking	Foremen	Coreroom Foremen
		Clerks (C.R. Dept Only)
		Office Expense
	Non Productive Labor	Moving Coreboxes
		Common Labor
		Handling & Mixing Sand
	Coremaking Materials	Sand
		Binders
		Arbors Rods Etc.
		Fuel

FIG. 3

No doubt there will be criticisms more or less important of the correctness of allocation of different cost factors. This was indicated by the divergent views of the members of the cost committee on several points, one of the most important points being in respect to which items of foundry expense are

ACCOUNTS		
CLASSIFICATION	ACCOUNTS	SUBDIVISIONS
COREMAKING CONT	COREMAKING MATERIALS CONT.	MISCEL MATERIAL
	MAINTCE OF COREMAKING EQ'PT.	REPAIRS TO OVENS
		" " CRANES
		REP TO MIXERS, CORE MCHS ETC.
		" & REN. OF HAND TOOLS
		" " " " MISC EQ'PT.
	DIRECT COREMAKING	COREMAKING TIME CHARGED TO PRODUCTIVE ORDERS
CLEANING	FOREMEN	CLEANING ROOM FOREMEN
		CLERKS (C.R ONLY)
		OFFICE EXPENSE
	LABOR	CLEANING ROOM LABOR
	MATERIALS	MATERIALS USED IN CLEANING
	MAINTENANCE OF EQ'PT.	REPAIRS TO BARRELS ETC
		" " CRANES
		" " SMALL TOOLS
PATTERNMAKING	FOREMEN	PATTERN SHOP FOREMEN
		CLERKS (PAT SHOP ONLY)
		OFFICE EXPENSE
	NON PRODUCTIVE LABOR	NONPRODUCTIVE LABOR
		COMMON LABOR
	NON PRODUCTIVE MATERIAL	LUMBER (EXCEPT ON PROD ORDERS
		GENERAL SUPPLIES
	MAINT'CE OF PATTERNMAKING EQ'PT	REPAIRS TO MACHINES
		" " MOTORS
		" " SHAFTING & BELTING
		" " MISC EQ'PT.
	DIRECT PATTERNMAKING	PATMAKING TIME CHGD TO PROD ORDERS
	" MATERIAL	LUMBER ETC " " " "

FIG. 4

more nearly proportionate to and should be assessed on the tonnage rather than the direct labor basis. These differences of opinion clearly show that no single arrangement of so many factors can meet with universal approval, but the proposed plan can be varied to any extent to suit conditions. The forms

Accounts		
Classification	Accounts	Subdivisions
Selling	Sales Department Salaries	Home Office Salaries
		Branch " "
		Estimating
	Office Expense	Home Office Expense
		Branch " "
	Commissions	Commissions
		Bonus
	Miscel. Expense	Salesmens' Expense
		Travelling
		Advertising
		Catalogues & Price Lists
Non Distributable	Transportation Outgoing (Included in Selling Price)	Freight & Express on Outgoing Shipments
Depreciation	Rent	Depn of Buildings
	Administration	" " Office Eq'pt.
	Power	" " Power Machinery
	Melting	" " Melting Eq'p't.
	Molding	" " Molding "
	Cleaning	" " Cleaning Room Eq'pt
	Coremaking	" " Coremaking "
	Pattern Making	" " Pattern Shop "

FIG. 5

merely indicate the opinion of the majority of the committee, but in the text will be found the suggested alternative arrangements which may be used to advantage.

It is assumed that books are kept, that some method of charging expenses correctly to certain accounts is in vogue, and

that an inventory is or can be taken at regular intervals depending upon the length of the period under review. It is not necessary to the successful working of the proposed plan to have the cost system tied into the books, but this can be done if desired. If it is not, however, the books must give sufficient information to accurately distribute all the expense incurred during the period under review. Therefore if the existing accounts do not give sufficient information to make the proper

BUILDING DEPRECIATION

B.M. NO.		VALUE	RATE %	ANNUAL DEPRCN.	MONTHLY DEPRCN.
1	MAIN BUILDING				
	STRUCTURE	8000000	2	160000	13333
	BUILDING EQUIPMENT	2000000	5	100000	8333
	TOTAL	10000000		260000	21666

FIG. 6

distribution without arbitrary divisions, additional ones should be opened.

The forms herewith comprise:

1. A suggested account classification. In the first column are the main classifications or heads under which the accounts are grouped. In the second column are the primary divisions of the main classifications. The book accounts should provide for the accurate charging of expenditures to at least these divisions. In the third column are sub-divisions of the primary divisions for the purpose of properly allocating the different expenses, or for carrying the expense distribution to a greater amount of detail if desired. Figs. 1 to 5.

2. A form for summarizing building depreciation. Fig. 6.

3. A form for summarizing the depreciation of mechanical equipment. Fig. 7.

4. A form where under the title "Rent Charges" are compiled and distributed to departments all expenses chargeable to the plant property and buildings. Fig. 8.

5. A form for the compilation and distribution to departments of the expenses of administration and general overhead. Fig. 9.

6. A form for the compilation and distribution to departments of the cost of power. Fig. 10.

7. Forms for compiling the data to be used in estimating and cost recording. These consist of the cost per pound of metal in good castings produced, the Overhead on direct molding, the overhead on direct coremaking, the cost of cleaning, the overhead on the direct patternmaking and the cost of selling. They are given in sufficient detail to show how the other forms should be constructed in case a greater degree of departmentalization is desired, and in the following will be suggested methods of consolidating some of the departments shown for smaller foundries where some of the departments shown are of small moment. Figs. 11 to 16.

8. A suggested estimating sheet for use in quoting prices Fig. 17.

The cost figures for a hypothetical plant have been worked out in order to show the actual application of the plan. These figures have purposely been made to indicate several points where costs are high to show how clearly such a condition will be apparent to an experienced management.

The first step is obviously the preparation of enough forms to suit the conditions, and the compilation of depreciation charges, unless these are book accounts. The use of columnar sheets will be found of assistance in this work.

Next comes the distribution of the expenses of the period under review each to its proper place on the forms.

The forms are ruled in columns from left to right as follows: first, account number column; second, account title; third, a column for letter denoting the proper column in which to make the entries for the various accounts; fourth, the "A" column into which only the actual expenses as shown by the books are entered, making the total of all entries in column "A" exactly agree with the total expense as shown by the book; fifth, the "B" column for extension of "A" column subtotals and amounts distributed from other forms; sixth, the "C" column reserved strictly for departmental totals.

It will thus been seen that the total of column "A" should agree exactly with the books, and that if to this total is added the total depreciation the resulting sum should agree very closely with the total of column "C" if the work has been correctly performed, thus proving the accuracy of the figures.

Rent Charges (*Fig.* 8).

Expenses originating from owning, leasing and maintaining property or buildings have been summarized under the classification of "Rent."

If the property is owned outright the owner may feel justified in charging into his costs a sum equipment to the rent which would be paid to another.

If the property is rented completely the accounts would be limited to only those which apply, and where the ground

DEPARTMENTAL EQUIPMENT DEPRECIATION

DEPT. NO.	DEPARTMENT	VALUE	ANNUAL DEPR'CN.	MONTHLY DEPR'CN.
	OFFICE	120000	12000	1000
	POWER	2000000	100000	8333
	MELTING	600000	42000	3500
	MOLDING	2500000	150000	12500
	COREMAKING	400000	32000	2667
	CLEANING	300000	30000	2500
	PATTERN SHOP	400000	20000	1667
	TOTAL	6320000	386000	32167

FIG. 7

is rented and buildings owned proper provision would have to be made.

When the expenses are completely entered in column "A" the total of these is entered in column "B" and to this is added the depreciation charge for buildings taken from the form of Fig. 6, giving the total rent charge which must be distributed to productive departments.

This distribution is made on the basis of the square feet in area occupied by each productive department and to accomplish this distribution the area occupied by each productive department is entered as shown, the percentage which each area is of the total area of all these productive departments is computed and the total rent charge is prorated on these percentages. The amount belonging to each de-

partment is entered in column "B", to be later transferred to the departmental charges.

Administrative and General Overhead (*Fig.* 9).

Administrative charges are those arising from the supervision and assistance which must be given to the men directly making the product together with expenses which are proportionate to the labor factor in the cost of the product.

The compilation and distribution of administrative overhead is accomplished very nearly as described for rent charges using column "A" for entering expenses from the

Acct. No.	Item			Entr. Col.	A Amount	B Extension	C Recap.
	RENT CHARGES						
	Rent (if Paid)			A	33333		
	Interest On Bonds & Mortgages			A	25000		
	Taxes On Real Estate			A	9000		
	Fire Insurance			A	12500		
	Maintenance Of Property			A	2000		
	Total Rent Expense			B		81833	
	Depreciation Of Buildings			B		21666	
	Total Rent Charge			B		103499	
	DISTRIBUTION						
	Department	Sq. Ft.	%				
	Office	930	3	B		3105	
	Power	1550	5	B		5175	
	Melting	1550	5	B		5175	
	Molding	18600	60	B		62099	
	Coremaking	4340	14	B		14490	
	Cleaning	2480	8	B		8280	
	Pattern Shop	1240	4	B		4140	
	Selling	310	1	B		1035	
	Total	31000	100	B		103499	

FIG. 8

books, column "B" for subtotals and distributed items, and reserving column "C". The basis of distribution is the relative size of the departments as indicated by the total payroll of each for the period under review.

If as is frequently the case the services of the executive officers of the company cannot be applied in these proportions, as for instance where the executives devote a greater proportion of their time to selling, an arbitrary distribution of their salaries should be made after the entry of this

ACCT NO.	ITEM			ENTRY COL	A AMOUNT	B EXTENSION	C RECAP
	ADMINISTRATIVE OVERHEAD						
	EXECUTIVE SALARIES			A	70000		
	DISTRIBUTION (ARBITRARY)						
	DIVISION		%				
	GENERAL OVERHEAD		50	B		35000	
	SELLING		50	B		35000	
	TOTAL		100			70000	
	GENERAL OVERHEAD						
	GENERAL SUPERVISION			A	30000		
	CLERICAL SALARIES			A	80000		
	OFFICE EXPENSE			A	4000		
	TAXES EXCEPT ON REAL ESTATE			A	5333		
	LIABILITY INSURANCE			A	20000		
	GENERAL EXPENSE (OFFICE)			A	12500		
	REPLACING DEFECTIVES			A	31000		
	TOTAL GENL. OVERHEAD EXPENSE			B		185833	
	50 % EXECUTIVE SALARIES			B		35000	
	RENT (OFFICE)			B		3105	
	DEPRCN. OF OFFICE EQPT.			B		1000	
	TOTAL GENL. OVERHEAD CHARGE			B		224938	
	DISTRIBUTION						
	DEPARTMENT	PAYROLL FOR PERIOD	%				
	POWER	65000	6			13496	
	MELTING	71000	7			15746	
	MOLDING	593800	55			123716	
	COREMAKING	151200	14			31491	
	CLEANING	110000	10			22914	
	PATTERN SHOP	42000	4			8748	
	SELLING	40000	4			8748	
	TOTAL	1073000	100			224931	

FIG. 9

Acct No.	Item			Entry Col.	A Amount	B Extension	C Recap.
	Power						
	Wages			A	71000		
	Material			A	61000		
	Maintenance of Machinery			A	9000		
	Purchased Power			A			
	Total Power Expense			B		141000	
	Rent			B		5175	
	General Overhead			B		13496	
	Depreciation of Machinery			B		8333	
	Total Power Charge			B		168004	
	Distribution						
	Department	H.P.H.	%				
	Melting	4100	17	B		28561	
	Molding	18000	62	B		104162	
	Coremaking	2200	8	B		13440	
	Cleaning	3000	10	B		16800	
	Pattern Shop	1000	3	B		5040	
	Total	29100	100	B		168003	
	Cost per H.P.H.	$0.058					

FIG. 10

item of expense in column "A" and the proportion applicable to general overhead and to selling should be entered in column "B" for future use.

The direct expenses applying to general overhead are entered in column "A", their total extended to column "B" and to these are added the percentage of executive salaries applicable to general overhead from above on this form, the rent charge from the distribution on the form of Fig. 8, to office, and the depreciation of office equipment from the form of Fig. 7. The total general overhead charge is the result.

The cost of replacing defectives is placed here for the reason that nearly always a defective is the result of some employee's error, and because it is a contingency which may originate in any department or on any job.

The distribution is accomplished by entering the total departmental payroll for the period under review, computing the percentage each payroll amount is of the total of all

and prorating the total general overhead charge on these percentages entering the prorated amounts in column "B" to be later transferred to the department charges.

As conditions vary in different foundries it may be thought desirable to prorate a portion of the general overhead charge on the basis of tonnage. If this is done the division is made arbitrarily as the judgment of the management may dictate, and on the form of Fig. 9, between the total general overhead charge and the distribution, the arbitrary distribution should be inserted as was the distribution of executive salaries above. The divided portions are placed in column "B" and that for inclusion with the tonnage charge is later transferred to the form of Fig. 11, while only the remainder is distributed to departments on the basis of payroll.

Power (*Fig.* 10).

The compilation of the cost of power is effected exactly as were the charges described. To the total power expense from the books is added the rent charge from the distribution on form 4 and the depreciation of machinery from the form of Fig. 7. The distribution is made by using the horse power hours consumed by each department, either actually measured or estimated as the basis for a percentage distribution. If no data exists the distribution would necessarily be an estimate of the percentage of the total power charge used in each department.

For comparative data a space is provided for recording the total cost of power per horse power hour.

Cost Per Pound Metal in Good Castings Produced (*Fig.* 11).

The object of this form is to compute the cost of a pound of metal in a casting ready to ship from the cleaning room, consisting of the cost of the metal itself, transportation and handling expenses, conversion cost, all losses including the cost of all remelting and such expenses as vary in proportion to increase or decrease of tonnage. The charge for metal and conversion and the tonnage charge are

compiled separately and combined so that the management may be supplied with more detail information for its guidance.

Expenses incident to the metal and its conversion are entered in column "A" and their total in column "B".

Acct No.	Item	Entry Col.	Amount	Extension	Recap
	Cost Per Pound Metal In Good Castings Produced				
	Melting				
a	Metals, Unloaded Including Frt.	A	140000		
	Melting Labor	A	7000		
	Melting Materials (Except Metals)	A	9200		
	Maintce Of Melting Eq'pt.	A	5500		
	Total Melting Expense	B		156500	
	Rent	B		5175	
	General Overhead	B		15746	
	Power	B		28561	
	Depreciation Of Melting Eq'pt.	B		9500	
	Total Melting Charge	B		162482	
	Tonnage Charges				
	Molding Materials	A	9200		
	General Expense (Manufacturing)	A	4500		
	Undistributed General Labor	A	7000		
	Total Tonnage Charge	B		10350	
b	Total Melting Chg. 162482				
	" Tonnage " 10350				
c	Cost Of Metal In G.C.P. 172482	C			172482
d	Net Wt. Good Cstgs. 4120000 Lbs				
		$	Cts.		
	Metals P.P.G.C.P. a÷d	0	0125		
	Melting P.P.G.C.P. b÷d	0	0145		
	Cost P.P. Metal In G.C.P. c÷d	0	0154		

FIG. 11

To this total are added in column "B" the rent charge from the distribution on the form of Fig. 8, the general overhead charge from the distribution on the form of Fig. 9, the power charge from the form of Fig. 10, and the depreciation of melting equipment from the form of Fig. 7. The total melting charge is the sum of these items.

The total tonnage charge is computed by entering in column "A" the expense of molding materials and such items as general expense (manufacturing), undistributed general labor, and others which are not clearly chargeable to departments.

If it has been decided that a portion of the general overhead is proportionate to tonnage that part should be charged here from the arbitrary distribution on the form of Fig. 9, which is not shown but described above.

If the cleaning department is not separately treated and it is decided that cleaning costs vary with tonnage they should be included here as will be discussed below.

If the pattern shop is too small to be departmentalized the expense incident to patterns may also be included here.

The total melting charge plus the total tonnage charge is the cost of all the metal in the good castings produced, which divided by the weight in pounds of good castings produced is the cost per pound of metal in good castings produced.

For additional information to aid in management the cost of metal alone is obtained by dividing the metals expenses including handling and freight by the weight of good castings produced. This average cost of metal only will be of service if special mixes are being estimated. The cost of metal and conversion including all losses is obtained by dividing the total melting charge by the weight in pounds of good castings produced. This cost is valuable as a guide in supervising melting practice.

When the cost of metal in good castings produced is obtained through the addition of melting and tonnage

charges the amount is also entered in column "C" for use later in proving work.

Overhead on Direct Molding. (*Fig.* 12).

The purpose of this form is to compute the percentage which when added to direct molding labor will absorb all molding overhead expenses.

The total indirect molding charge computation needs no further comment. After it is finished the cost of direct molding is entered in column "A".

ACCT NO.	ITEM	ENTRY COL.	A AMOUNT	B EXTENSION	C RECAP.
	OVERHEAD ON DIRECT MOLDING				
	FOREMEN	A	21000		
	NONPRODUCTIVE LABOR	A	135000		
	MAINTCE. OF MOLDING EQ'PT.	A	14000		
	REPAIRS TO PATTERNS & FLASKS	A			
	TOTAL INDIRECT MOLDING EXPENSE	B		220000	
	RENT	B		62077	
	GENERAL OVERHEAD	B		123716	
	POWER	B		104162	
	DEPRCN. OF MOLDING EQ'PT.	B		12500	
	TOTAL INDIRECT MOLDING CHARGE	B		522477	
	DIRECT MOLDING	A	355000		
a	PRODUCTIVE MOLDING	355000			
b	TOTAL INDIRECT CHG.	522477			
c	TOTAL COST MOLDING	877477	C		877477
	b÷a x 100 = % O.H. ON MOLDING	147 %			

FIG. 12

The addition of the cost of direct molding and its indirect charge will result in the total cost of molding which is entered in column "C".

The percentage which the total indirect molding charge is of direct molding is the percentage which must be added to direct molding cost to cover overhead expense.

Conditions in some foundries may be such that more accurate costs of individual castings will result from applying certain items of molding overhead expense on the tonnage basis. In such cases the items to be applied should be inserted under "Tonnage Charges" on the form of Fig. 11.

Overhead on Direct Coremaking (*Fig.* 13).

This form is treated precisely as was the form of Fig. 12.

Cost of Cleaning (*Fig.* 14).

The computation of the total cleaning charge is effected in the same manner as in the preceding.

In the form as shown this charge is reduced to a cost per pound merely to illustrate one way of treating the cleaning charge, but conditions vary so widely in different foundries that no single method of applying cleaning costs can be suggested without the danger of causing confusion.

If the cleaning cost is not large it may be thought best to include it among the other overheads. If it varies in

Acct. No.	Item	Extn. Col.	A Amount	B Extension	C Recap.
	Overhead On Direct Coremaking				
	Foreman	A	17500		
	Nonproductive Labor	A	31000		
	Coremaking Materials	A	36000		
	Maintce. Of Coremaking Eqpt.	A	1200		
	Total Indirect Coremaking Expense	B		85700	
	Rent	B		14496	
	General Overhead	B		31491	
	Power	B		13440	
	Deprcn. Coremaking Eqpt.	B		2661	
	Total Indirect Coremaking Charges	B		147788	
	Direct Coremaking	A	89000		
a	Direct Coremaking 89000				
b	Total Indirect Chgs. 147788				
c	Total Cost of Coremkg. 236788	C			236788
	b÷a x 100 = % O.H. On Coremkg. 166%				

FIG. 13

ACCT NO	ITEM	ENTRY COL	A AMOUNT	B EXTENSION	C RECAP
	COST OF CLEANING				
	FOREMEN	A	15000		
	CLEANING ROOM LABOR	A	95000		
	MATERIALS	A	2500		
	MAINTCE. OF EQPT.	A	2000		
	TOTAL CLEANING EXPENSE	B		114500	
	RENT	B		8250	
	GENERAL OVERHEAD	B		22494	
	POWER	B		16800	
	DEPRCN. OF EQPT.	B		2500	
a	TOTAL CLEANING CHARGE	C			164574
b	NET WT. GOOD CSTGS. 1120000 LBS				
	COST P.P. OF CLEANING a÷b = .0015				

FIG. 14

proportion to the weight of castings the expenses charged here may be included in the tonnage charge, and the form of Fig. 14, omitted entirely, or if it varies more nearly in proportion to molding time they may be charged into the overhead on direct molding.

Whether the basis of charging is classified weights, other classifications, time, piece prices, etc., the method must be developed to suit conditions, the important point, however, being that no matter what the basis of charge the unit cost must be that which the volume of work during the period will absorb completely.

Overhead on Direct Patternmaking (*Fig.* 15).

The treatment of this form needs no further explanation if the pattern shop is departmentalized.

If the pattern shop is to small to be a factor in production the expenses incident to it may be included elsewhere as conditions may warrant. Inasmuch as under these conditions pattern expense will probably bear no relation to any departmental charge it may be included in

the tonnage charge as referred to under the form of Fig. 11.

Selling Cost (*Fig.* 16).

Selling expenses are entered in column "A" and their total in column "B" as for other departments.

The rent charge from the form of Fig. 8 is entered in column "B". That part of executive salaries chargeable to selling and the general overhead charge are entered in column "B" from the form of Fig. 9. The total selling charge is entered in column "C".

The computation of the percentage which must be added to all shop costs to include the cost of selling or sales burden is made by adding all column "A" entries on all forms, which as has been explained represents the money spent during the period both directly and indirectly in production. If to this total are added the depreciation charge for buildings and equipment from the forms Figs. 6 and

ACCT NO.	ITEM		ENTRY COL.	A AMOUNT	B EXTENSION	C RECAP
	OVERHEAD ON DIRECT PATTERNMAKG.					
	FOREMAN		A			
	NONPRODUCTIVE LABOR		A	11000		
	NONPRODUCTIVE MATERIAL		A	4000		
	MAINTCE. OF EQUIPMENT		A	1500		
	TOTAL INDIRECT PATTERNMAKG. EXPENSE		B		16500	
	RENT		B		4140	
	GENERAL OVERHEAD		B		8998	
	POWER		B		5040	
	DEPRECIATION OF EQUIPMENT		B		1667	
	TOTAL INDIRECT PATTERNMAKG. CHARGE		B		36345	
	DIRECT PATTERNMAKING		A	31000		
	DIRECT MATERIAL		C	25000		25000
a	DIRECT PATTERNMAKING	31000				
b	TOTAL IND. PATMKG. CHG.	36345				
c	TOTAL COST OF PATMKG.	67345	C			67345
	b÷a×100=% O.H. ON PATMKG.	117 %				

FIG. 15

7, the resulting total is obviously the total cost of the product including the expense of selling or the total cost of sales. Deducting the selling charge leaves the manufacturing cost and the percentage which the selling charge is of the manufacturing cost is the sales burden per cent.

Proof of the accuracy of the work is obtained by adding all of the column "C" entries, which should check with the total cost of sales.

Expenses Not Included.

It will be noted that delivery costs on outgoing shipments are not included in the factory accounting. As this expense is incident to the location of the customer and has no relation to the cost of production, provision has been made for its addition on the suggested estimating form.

ACCT NO.	ITEM.	ENTER COL	2 AMOUNT	3 EXTENSION	5 RECAP
	SELLING COST				
	SALES DEPT. SALARIES	A	40000		
	OFFICE EXPENSE	A	16000		
	COMMISSIONS	A	21000		
	MISCEL. EXPENSE	A	4500		
	TOTAL SELLING EXPENSE	B		81500	
	RENT	B		1035	
	50 % EXECUTIVE SALARIES	B		35000	
	GENERAL OVERHEAD	B		8988	
a	TOTAL SELLING CHARGE	C			126523
	TOTAL COL A	316866			
	DEPRCN. OF BUILDINGS	21666			
	" " EQUIPMENT	32167			
	TOTAL COST OF SALES	3222699			
	LESS a. TOT. SELL'G. CHG.	126523			
	b. MANUF'G. COST	3096176			
	a ÷ b x 100 = SALES BURDEN	4.1 %			
	TOTAL COST OF SALES (DISTRIBUTED)	C			3222699

FIG. 16

Discounts for prepayment are sometimes charged to selling expense but are here taken care of in the estimate.

Interest on investment is another item which is frequently included in costs, as is sometimes interest on borrowed money. These can be included in the cost if desired or an additional financial overhead can be added in estimating to include them.

Other Departments.

Should it be deemed advisable to further departmentalize the organization sufficient information has been given to enable the cost accountant to construct any additional departmental forms, as for instance, dividing the molding department further into bench, floor and machine departments; departmentalizing shipping and delivery; or any other subdivision of or addition to departments.

Estimating Sheet (*Fig.* 17).

It is suggested that in order to make sure of the inclusion of all cost factors in making estimates for quoting prices, a standard form of estimating sheet be used. The form here shown is suitable for either piece work or day work for the direct labor.

The weight of the casting is first calculated with allowance for finish.

If a mix more or less expensive than the average as shown for "Metals P. P. G. C." the form of Fig. 11 is to be used the cost per pound metal in good casting produced can be adjusted.

The direct patternmaking is estimated and entered at cost.

The overhead percentage on direct patternmaking from the form of Fig. 15 is computed and entered.

Pattern material is estimated and entered.

Direct molding is estimated and entered at cost.

The overhead percentage on direct molding from the form of Fig. 12 is computed and entered.

Direct coremaking is estimated and entered at cost.

The overhead percentage on direct coremaking from the form of Fig. 13 is computed and entered.

Cleaning cost, flask labor and flask material are estimated and entered.

The total of the foregoing is the estimated manufacturing cost to which is added the percentage for sales burden from the form of Fig. 16 giving total cost.

ESTIMATING SHEET

QUAN.	ITEM	@	EST.	ACT.
4	Cast Iron Cylinder			
	1000 LBS. IRON TOTAL STD MIX	0154	1540	
	ADJUSTMENT FOR SPECIAL MIX			
	DIRECT PATTERN MAKING COST	1.00	500	
	O.H. ON "	117%	585	
	PATTERN MATERIAL	10	50	
	DIRECT MOLDING COST		600	
	O.H. ON "	147%	882	
	DIRECT COREMAKING COST		300	
	O.H. ON "	166%	498	
	CLEANING COST	.0015	150	
	FLASK LABOR	60	60	
	" MATERIAL	05	50	
	MANUFACTURING COST		5215	
	SALES BURDEN	4.1%	214	
	TOTAL COST		5429	
	PROFIT	15%	814	
	CONTING. FOR DEFECTS BEYOND NORMAL		700	
	" " SLOW PAY			
	FREIGHT	.08	80	
	TOTAL SELLING PRICE		7023	

FIG. 17

The profit percentage is next added and any contingencies which should be covered. Freight on delivery is added net for reasons already discussed. The cash discount quoted and any other information necessary should be noted and the estimate filed.

If desired, when shipment is made or as the work progresses the actual cost figures may be recorded on the same sheet for comparison

Certain basic features are important. The books of account should be so arranged as to give the information required for cost work as directly as possible. An inventory of supplies should be kept and means employed to charge into the proper accounts all material used. The payroll should be so handled as to facilitate distribution to departments, and an accurate timekeeping system should be in vogue.

It will be found that depending on the volume of business the cost factors will not be uniform from period to period. As soon as sufficient data is available the proper rates and overheads for a normal volume of business should be determined. These normal rates may be used in estimating and cost recording so that when business volume is large and costs low the product will not be sold too cheaply and when the conditions are the reverse quotations will not be so high as to interfere with sales. When the normal rates are put into use reserve accounts should be employed to adjust the difference between normal and actual overheads thus recording the effect of volume of business.

Cost recording can be carried to any degree of refinement, depending upon the value of the records of the cost of work as a guide to sales and management policies.

For certain foundries with unifom product recording may be very simple. For others recording by jobs only may be required. Others should have costs recorded by customers or by classes. These or any of the varying combinations may be used depending upon the circumstances, and forms needed, should be developed accordingly.

Respectfully submitted

J. Roy Tanner, *Chairman*
H. J. Koch
W. B. Greenlee
L. S. Peregoy
G. D. Piper

Report of A. F. A. Representative on Joint Committee on Investigation on Phosphorus and Sulphur in Steel

Your representative on the Joint Committee on Investigation of Phosphorus and Sulphur in Steel has utilized the A. F. A. *Bulletin* to give you information regarding the developments of special interest to steel founders in this joint investigation. Periodically, information has been issued to the technical press by the sub-committee on publicity. As a result of these means for acquainting those interested with the activities of the joint investigation, there seems to your representative to be no necessity for an exhaustive report by him at this time of the work that has been done. Eventually a complete report will be issued by the joint committee, to serve the purpose of advising not only the technical organizations represented in the investigation, but the entire technical world, of the accomplishments. The comprehensive nature of the research is such as to require, ultimately, much time alone for the preparation of this report.

Much effort has been directed in one branch of the investigation which has been completed. This relates to the effect of sulphur on rivet steel, which varied from 0.10 to 0.15 per cent carbon. The prominent part taken by the United States government in this joint investigation, through the cooperation of the bureau of standards, the war department, and the navy department, prompted an early decision by the committee to use technologic papers issued by the bureau of standards as official media of reporting the results achieved. The desirability of announcing as quickly as possible the results of the inquiry as to sulphur in rivet steel, has made it seem advisable to report in condensed form this phase of the investigation at the forthcoming convention of the A. S. T. M. The bureau of standards agreed to this appropriate measure.

Believing that the preliminary report just referred to would prove of interest to yourselves and thinking a discussion of it at the A. F. A. convention might result in benefit to the more intelligent discussion of it at the subsequent A. S. T. M. meeting, your representative suggested to the chairman of the joint committee, and to the secretary of the A. S. T. M. that sufficient copies of the A. S. T. M. preprint containing the report on effect of sulphur on rivet steel be secured by the A. F. A. to be distributed to those present at the A. F. A. session to which your representative's report is submitted. Consent to do this was readily and courteously granted. But it is regretted that there was not sufficient time available, despite quick action by all concerned including that taken to favor the A. F. A. by the secretary of the A. S. T. M., to make possible the mailing of these preprint copies to you in advance, so that you might study the data in the report before discussing it here. You will have opportunity to do so prior to the formal presentation of it at Atlantic City, on June 28, 1922, at the annual meeting of the testing society. The date mentioned is tentatively selected for a steel session, which happens to be this year of very great interest to steel foundries. It is therefore hoped that many of you may find it practicable to attend the meeting of our sister society whose co-operation with us is on a most cordial basis.

The special manufacture for this investigation of three other classes of steels besides rivet steel, graded accordingly to customary carbon content in commercial practice, has been in progress. The Bethlehem Steel Co. and the Cambria Steel Co. have co-operated with the committee in this matter. It will be seen in the report of rivet steel sulphur tests that the Carnegie Steel Co. made the steel especially for those tests. As to steel castings, which represent one of the 6 groups of material in series A, the questionnaire to steel founders, issued February 14, 1921, by the sub-committee on statistics, brought in some steel castings and data which it is believed will be helpful in the final drawing of conclusions. Series A covers steels in which the sulphur and phosphorus are residual. Series B covers steels in which sulphur may be added during the latter

stages of manufacture, before the metal reaches the mold. As a check on results from steels to which iron sulphide was purposely added after tapping, it was arranged that portions of some of the series B ingots should be remelted. Thus the effects of added and residual sulphur may ultimately be compared.

Any foundryman who has steel castings high in phosphorus or sulphur or both, or reliable data relating thereto obtained from laboratory or service tests, is requested to communicate with Prof. H. L. Whittemore, chairman, sub-committee on statistics, at the United States bureau of standards, Washington. This committee has been diligent in seeking information on the subject from every reliable source at home and abroad.

A careful reading of the preliminary report now in your hands will indicate the care taken to get at the bottom of the old controversy regarding sulphur in steel. The 16 committee members, represent 11 technical organizations, and include consumers and producers in almost equal ratio, besides neutrals having a purely scientific interest. Such a neutral heads the joint committee, in the person of Dr. Geo. K. Burgess, chief, division of metallurgy of the bureau of standards. Your representative feels that the attitude of the committee members, as manifested in this investigation, has demonstrated the fact that they have forgotten any prejudices they may have held, and that they are attacking the problem of ascertaining the effects of phosphorus and sulphur in steel in a manner which is as scientific as it is practical, and as fair-minded as it is comprehensive.

Respectively submitted,

R. A. BULL

A. F. A. Representative on Joint Committee on Investigation of Phosphorus and Sulphur in Steel

A New French Electric Furnace*

By R. Sylvany

The greatly increased application of electrometallurgy has directed fresh attention to the different types of electric furnaces capable of being successfully employed for melting and refining metals. Many types of furnaces have already been adopted in industrial practice and have been widely installed.

The furnace described in this paper, the idea of which is due to T. Levoz, a French metallurgist, presents certain interesting features, and illustrates one of the latest French developments in this field. The use made of it during the war for the production of high speed steel demonstrated the principles on which it is constructed and which we shall briefly describe.

The refining of a steel bath is effected by the action of the slag, of a fixed composition, on the molten metal. This action is made up of several reactions which require for their realization certain conditions already laid down by Prof. Campbell in the course of a meeting of the British Iron and Steel institute, when the first practical trials of electric furnaces were being made.

The slag must be brought to a high temperature, as this temperature and the resulting fluidity combine in facilitating the refining reactions. The rapidity of these reactions, indeed, increases with the temperature, the increase being much more than proportional.

The great fluidity maintained in a basic slag and the formation of calcium carbide by the action of the arc upon the limestone slag are two conditions which favor desulphurization.

The thorough rabbling of the bath is indispensable, as it is necessary that every part of it in succession shall be brought in contact with the slag so that it may free the metal of its impurities. This rabbling must be secured by a suitable distribution of the current.

*Contributed through the courtesy of the Association Technic de Fonderie de France.

For this reason Prof. Campbell laid stress upon the following important points, the realization of which appeared to him essential:

The furnace should be closed as much as possible and should be of the simplest possible construction; the furnace should be entirely separated from the electrical fittings of the generators and transformers, which should be maintained at their highest capacity in order to increase the power of the installation; the wear of the refractory materials of the linings should be saved by applying the heat at the center of the bath, and those of the roof by protecting them from the direct radiation of the arc by the electrodes themselves; the slag should be given as large an area as possible so as to increase the refining surface; and the temperature of the slag should be maintained above that of the steel, so as to secure fluidity and facilitate the high basicity required by an intensive refining process.

Prof. Campbell also advised the use of a homogeneous and solid hearth, and with this in view, recommended that electrodes should not be allowed to pass through it. On the other hand, Dr. W. Borchers, who was one of the pioneers of electrometallurgy, was speaking of the satisfactory results obtained by this latter type of furnace. The principle of this, the Girod furnace, was based on a combination of the resistance arc furnace. The metal to be melted constituted one of the electrodes, the slag covering it forming an electrolytic conductor, the metal constituting the resistance and the current being distributed by one or several carbon electrodes traversing the roof and by multiple contacts passing through the bottom. There was no question of the solidity of this furnace. The advantages arising from a uniform distribution of the current, effected by the arrangement of the contacts passing through the bottom, constituted one of its essential characteristics, namely that of insuring the efficacity of the furnace's refining action.

The section and length of these contacts were such that no one of them could carry more than a certain fraction of the total current without becoming overheated and, consequently, without its resistance being excessively increased. The regulation of the

temperature and resistance of each contact was effected by cooling the hollow extremities by a water circulation system. Certain inconveniences were thus remedied, and as a result of the uniform arrangement of the contacts round the prolonged axis of the carbon electrodes the advantage of a uniform rabbling of the bath was obtained. Prof. Campbell's one objection thus disappeared; moreover, the results already obtained at that time demonstrated the furnace's merits.

Life of Lining

When regularly working, the lining, which was chiefly composed of burned dolomite, withstood at least 80 heats. The bottom of the furnace stood 120 to 160 heats without repair and had then lost 100 millimeters in thickness. With charges of molten metal the lining could stand 200 operations, and the roof about 20 to 35. The wear of the other parts of the furnace was comparatively slight and the consumption of carbon electrodes was from 12 to 15 kilograms per ton of steel.

The principle adopted in the Girod-type furnace, which was also to be adopted in the Keller-type furnace with a better distribution of current, thus marked an advance in the construction of electric furnaces.

In the Keller-type furnace the distribution of the current in the bath, instead of being merely carried round a certain number of contacts, was effected over the whole depth of the bath by means of a bundle of iron bars surrounded by refractory clay which formed the furnace bottom. The current was introduced by a large carbon electrode rectangular in section.

As in the Girod-type furnace, the intensity of current necessary was high, as it had to reach 3000 amperes; but this high intensity had fewer disadvantages as the current was better distributed and the electric resistance in the large single electrode and in the conducting hearth was not as great. The difficulty of water cooling and of overheating of the carbon electrodes was avoided.

The principles laid down by Prof. Campbell therefore were observed in this furnace, notwithstanding the fact that the conductors passed through the hearth.

On the other hand, it might be objected that they were not followed in the first furnaces of the Heroult type, in which the better basic action was counteracted by the imperfect closing of the furnace, which was opened by three lateral doors and had the two electrodes passing through it from the roof. Nevertheless the effectiveness of the furnace was not as great as it might have been, although the rectangular surface of the bath was extended, because of the action of the arc being concentrated only in the vicinity of the electrodes. The intensity of the current alone was greatly reduced. The rectangular section, therefore, was unsuitable and at Remscheid it was reduced only to the zone of action of the arcs. The circular form introduced by Nathusius seems to be preferred, and it was this form of section which Heroult adopted for the 15-ton furnace which he built in the United States.

A New Type of Furnace

All these considerations led the inventor previously mentioned to produce a special type of electrical furnace, in which the principles already indicated were further developed and the various defects were minimized.

He sought on the one hand, to secure rapidity of fusion and on the other to insure good purification by making the current pass as directly as possible—but at the same time with uniformity of distribution—through the metallic mass and the slag, the furnace being simple in construction, strong and well closed, without an excessive intensity of current being necessary.

For this purpose he constructed a close crucible with only one opening for charging the material and the additions and for pouring the finished metal. He also placed the large carbon electrode in a sheath to obviate air currents in the space left free between the electrode and the roof. Thus he facilitated a better basic action.

Moreover, certain trials made for the first time at the electric power station of the commune of Jambes in Belgium enabled him to discover the possibility of placing electrodes in the lateral linings of the crucible without their being affected by wear at that level.

In fact, as the lateral linings of the furnace presented a larger surface than that of the hearth (bottom) the number of iron conductor bars embedded in the linings can be increased so that their section can be lessened.

Thus a strong magnesite bottom can be composed which resists the action of overheated metal much better than an armored hearth.

Wires of 6 to 10 millimeters were found sufficient to obtain currents of 1200 to 1500 amperes at 85 volts capable of developing the temperatures necessary for the purification of the entire mass notwithstanding the depth of the bath.

The electric resistance of the conductor electrodes thus constituted is almost negligible, for, as has already been pointed out, the surface of the linings permits bringing into play a considerable number of wires equivalent to such a large conductance section that, without taking account of the conductivity of the bottom the loss is already practically nil.

The use of small section metal conductors, tends to produce a more uniform circulation of the electric current than the use of large section conductors, and the large surface of the positive carbon electrode is well utilized owing to the excessive splitting up of the current at the surface of the bath.

The slag is highly and uniformly heated throughout its surface, and its temperature may be raised to the point required to secure good fluidity and intense chemical action.

Two Rows of Electrodes

To facilitate the process of refining still further the inventor was led to adopt a special device which consists in introducing two rows of superimposed lateral electrodes, the lower ones being termed fusion electrodes and the upper ones refining electrodes.

The fusion electrodes, which vary in number with the capacity of the furnace, are formed by a bundle of pure iron wires imbedded at the base in a mixture of magnesia and tar and united at the top so as to give a good contact with the metal contained in the crosswise channels arranged in the furnace hearth.

These electrodes are joined in series by a copper bar, which is itself connected by cables to the negative pole of the current transformer. The refining electrodes, which are placed on a level above that of the others, facing the slag, are also variable in number according to the capacity of the furnace.

A special device enables the current to be taken from the fusion electrodes and afterwards from the refining electrodes, or alternatively from both rows of electrodes at once.

The number of wires forming the electrodes, as also the section of these wires, varies with the capacity of the furnace. The wires of the fusion electrodes have always a larger section than those of the refining electrodes.

In every case the current enters by a large vertical carbon electrode passing through the furnace roof, its horizontal section being half that of the furnace crucible.

When direct current is employed this large positive electrode is hollowed out and forms a heat reflector; moreover the oxygen of the bath is liberated and is carried to the positive pole instead of remaining in the bath and oxidizing it.

The furnace proper consists of a steel plate body with a nonconducting refractory lining and fitted with a cover. Hollow trunnions, through which the conductor cables pass, enable the whole apparatus to be tilted.

In this furnace the current always passes through a layer of relatively thin metal, which enables currents of much low intensity to be used. An intensity of 1500 amperes is not exceeded; nevertheless the temperatures obtained are diffused throughout the entire mass of the slag and metal.

As was mentioned at the beginning of this paper, this furnace was employed during the war in the production of high-speed steel. It was installed at the Jarville works of the Eclairage Electrique Co., near Nancy, now amalgamated with the Thomson-Houston Co. The results obtained appear to indicate that, with continuous working and by treating 1000 kilograms per heat with an amperage of 3000 at 80 volts it would be possible with one furnace to obtain an output of eight tons per day by deoxidizing the metal obtained from a converter.

Analysis Control in Acid Electric Steel Practice

By A. C. Jones, Chicago

Accuracy of analysis control has been attained by some melters, but the writer believes the majority are not maintaining uniform accuracy with reasonable consistency. Melters will agree that reasonable consistency should allow a leeway of five points over or under the desired content. Perhaps some would feel that on carbon control the range should not extend over three points in either direction. With such a standard set for silicon, manganese and carbon, the carbon would show less deviation from the desired analysis. It is fortunate for us that carbon can be controlled a little better than silicon or manganese, but even the off-silicons and off-manganeses sometimes are exceedingly expensive and a closer control is greatly desired.

If it were possible to have exactly the same conditions attending every heat, we might have an easier time getting what we want, but there are so many powerful influences working to destroy the equilibrium that a man must be alert to think his heat through and obtain the desired analysis when things do not work out as usual.

Although much depends on the close observation of the heat all the way through from start to finish, there are certain suggestions which can be worked up into a schedule of operation. First, however, some general remarks are in order.

Too Many Changes in Practice Costly

In making steel many foundrymen change the melting practice too often. When trouble occurs with the castings which may or may not be due to the metal, a change is thought necessary which possibly means a more expensive practice. Then when everything goes smoothly as far as the quality of metal and even operation are concerned, an effort is made to cut down on the expense in some way. This brings further changes which

sometimes are converted into more trouble. A change in practice should not be made once this phase has been carefully and thoughtfully adopted unless there is a strong reason for it.

Sometimes there is a tendency to start out with a fine program and to gradually change it little by little. After fairly good results have been obtained for a long period a review of the original schedule will show that many little points which affect the analysis and cost of the steel have been neglected. Then we start over again to be careful. Although it is necessary for the melter to depart from a possible schedule of additions sometimes, if the conditions are made as uniform as possible there should not be need for it often.

The first heat from a cold furnace often is harder to bring to the desired analysis than the following ones. If the interval between this and the former heat is not over three hours, charging the furnace directly after pouring the last heat would not affect the working of it. If the interval is greater, charging immediately before the power goes on is better, unless the atmosphere of the furnace can be made non-oxidizing immediately and furnace sealed tightly. This is hard to accomplish. Charging in advance causes considerable oxidation, particularly with material such as turnings, flashings and stock having great surface area. The result is that by the time the power goes on there is a heavy scale on all parts of the charge. This gives a thin slag, the bath melting down low in silicon, manganese and carbon. This also is hard on the roof and lining, particularly with furnaces of heavy power input where the violence of the arc causes considerable splashing of this thin slag against those parts of the furnace. This may be compensated by charging some of the heavier stock first and adding the turnings, etc., just before starting the heat.

Once the power is on, it should not be taken off unless absolutely necessary until the charge is in a molten condition. If there is any work to be done such as changing electrodes, it should be taken care of before starting unless only a minute or two will be used. When parts of the charge are heated to a temperature ranging from 1500 degrees Fahr. to the melting point, excessive oxidation or scaling takes place and the slag

becomes rich in iron oxide. This condition is still more aggravating where the furnace is not kept air-tight during the melt down.

All will admit the furnace should be kept well sealed. This means not only a saving in time and energy, but helps to give a uniform blanket of slag on the melt down of each heat, all other conditions being the same. This is more important on furnaces that melt slowly and where the volume of oxygen passing into the furnace is much greater because of the longer melting time. Not only is there a benefit in time, energy and control, but there is an economy in electrode consumption due to oxidation of the electrodes.

Another factor in analysis control is the silicon, carbon and manganese content of the charge going into the furnace. It would be folly to state here the requirements for all furnaces. This has to be worked out at each plant. The writer has aimed to get sufficient silicon, manganese and carbon in the charge so that when the heat is melted and fairly hot and the finishing of the heat is to start, the silicon will be about .07, manganese .09; and carbon about .13 per cent. If the nature of the charge has to be changed, and the silicon and carbon come higher on the charge average, a certain calculated amount of ore must be added. Melting down to the above analysis gives a nice thin slag that is not so oxidizing as to leave the bath highly saturated with oxide. It is desirable to get the residual as low as .07 for silicon, .09 for manganese and .13 for carbon, because at this point the steel starts to hang on tenaciously to these elements. Therefore, if the proper mixture is used all of the heats will come close to the above analysis from which the step-up can be made with good duplication. If on the other hand a mixture higher in metalloid content is used, some heats on account of greater oxidation will get to this level while other heats being less oxidized will have a much higher residual content and the final analysis will show high results. In other words, the idea is to melt down to a similar condition as is obtained in converter practice and then to step-up quickly to the desired analysis. We know that control of analysis is a little less difficult in converter practice than possibly in any other process except the

crucible—particularly when the metal is blown completely down. If it happens to show a greater degree of oxidation than usual we can readily calculate that not more than a certain number of points will have to be added extra. The danger of a bath with lower analysis—say .03 silicon, .04 manganese and .07 carbon—is that an unknown amount of oxide is dissolved in the steel, which neutralizes the effect of a part of the additions.

The writer has found that with the Moore-type electric furnace melting a 3½ ton heat in one hour and 20 minutes, the mixture analysis to give the above residual content is about .22 silicon, .63 manganese and .30 carbon, using 50 per cent shop scrap and about 30 per cent turnings, the remainder being forgings and shearings. The manganese is not considered important as it depends much on the actions of its partners, silicon and carbon. If they are high the manganese will stay also.

Let us consider each element by itself and look for the causes of erratic analysis and determine how to deal with the conditions. In discussing these points the writer is adhering to the idea before mentioned of a rather low residual content when the finishing of the heat is started.

Causes of Low Silicon

A lower silicon than desired is due to an excessive amount of iron-oxide in melting down. An excess of iron-oxide may be due to too much oxygen over a short or long period entering into the melting chamber and attacking the steel during that time. This is aggravated if there is not sufficient silicon, manganese, and carbon in the charge to neutralize some of this oxidizing power. Scrap with excessive rust and having a large surface area exposed to whatever oxygen may be about will cause an increase in iron oxide. A low silicon and carbon content of the charge will cause a more oxidized bath and slag, all other conditions being the same.

To prevent such a condition, the furnace should be kept as air-tight as possible even after all is melted. The condition of the charge should be kept as uniform as possible, both as to analysis and physical condition. If there is more rust and some of the material is lighter, the silicon content of the charge

should be increased slightly. In the first heat out of a cold furnace a longer time usually is required for melting. This heat should have a higher silicon and carbon content than the others.

If after an attempt has been made to prevent it, a thin oxidizing slag persists, the best thing to do is to slag off some of it so that less than the usual amount remains on the surface of the bath. Then add three or four shovels of sand, preferably silica sand, spreading it well so that it will be incorporated evenly and quickly into the slag. More may be necessary, but observation of the slag will show this, it becoming a little viscous when sufficient has been added and the steel is fairly hot. After the slag has been prepared in this manner, the bath should be rabbled to bring the steel in the lower part of the bath in contact with the slag. This helps particularly in quick melting where often the surface steel is properly deoxidized while the bottom is full of oxide. Silicon pig is then added to raise the charge to the normal silicon content on the melt-down. The increase is perhaps 8 to 10 points, allowing a little for loss.

The silica analysis of a proper finishing slag should be between 50 and 60 per cent. With a higher silica content the slag becomes a little too thick for good roof and lining life. A thin, watery, oxidizing slag will vary between 15 and 30 per cent silica content.

Causes of High Silicon

High silicon is usually due to either a higher melt-down than usual where the oxidation of the elements silicon, manganese and carbon was much less than normal, or to an excessive reduction of silicon in the slag with the aid of carbon.

The first condition will be noticed as temperature tests are taken; the metal will lay very quiet. Adding a shovel or two of ore as soon as possible will help. A reduction in amount of silicon to be added also is advisable. The amount to cut down, of course, depends on the melter's observation.

Reduction of silicon from silica has been a bugbear in the operation of many electric furnaces. Where the carbon content of the steel is above .25 per cent, considerable reduction takes place as the temperature goes up. A charge high in carbon

melting down to .25 so that little carbon has to be added will pick up a good bit of silicon if the slag is right. With the high temperature obtained under the three electrodes, the reduction is greatest in these regions.

However, if the bath is kept at the carbon content of the proposed melt-down analysis of .15 per cent, practically no reduction takes place. Then if the carbon is added at say 2 to 3 minutes before the power is finally taken off and this time that the power is on after the carbon addition is kept the same, one heat after another, the silicons will show a surprisingly small variation, where other conditions are constant.

At the plant with which the writer is identified, the present practice in adding carbon for a regular heat of .25 carbon is to dip two of the electrodes into the steel just before adding the manganese. The power is on only for exactly two minutes, checked by a stop watch. The pick-up of silicon cannot vary much when this is done. The danger of high silicon from heats calculated to finish with carbon much higher than .25 is negligible, as the increase is obtained by dipping the electrodes at the end of the melt, after the power is off, to obtain the extra carbon.

To give a nice deoxidized slag and keep the silicon, carbon and manganese stationary to the end of the heat, we have been using lately about 25 pounds of pea-size hard coal to a 3-ton heat. This is being added about 20 minutes before the heat is finished and is spread over the slag as uniformly as possible. Chestnut-size coal was tried, but it seemed that some of the heavier pieces penetrated the steel to a certain extent, raising the carbon indefinitely. Using the pea-size has eliminated this irregularity. There is a little pick-up of silicon by the bath, but this will be the same on all heats if it is introduced at the right time. This amounts to about 5 points.

A greater loss of silicon, manganese and carbon in melting down is experienced with a furnace melting slow and using graphite electrodes, than the same furnace with greater transformer capacity and using carbon electrodes. The oxygen in the chamber is readily changed to carbon dioxide by the carbon electrodes leaving a more neutral atmosphere and, therefore,

allowing less oxidation. However, graphite is not so easily attacked as the loss in pounds of electrode per ton indicates. Such opposite conditions may explain the varying amounts of silicon, manganese and carbon additions used in electric furnaces of different plants.

Solving Problems of Carbon Control

The steel seldom picks up carbon in the same sense that silicon is said to be gained. High carbon sometimes comes unexpectedly because of malfunctioning of the automatic control at the end of the heat. If an electrode breaks off and becomes partly submerged, the carbon rises rapidly. Watching the board is about the best precaution possible. The hazard of high carbon is greater with the use of amorphous carbon electrodes than with graphite ones. The rate of absorption by the steel from a broken electrode is much more with carbon than with graphite.

To bring down the carbon in such cases, unless it is hopelessly high, it is advisable to keep the power on and add sand to the slag to make it more silicious. The carbon then reduces the silica of the slag and the bath therefore loses its carbon. It usually is advisable to rabble the bath well after the electrode has been fished out and a sample should be analyzed immediately for carbon. To facilitate the lowering of the carbon the bath should be rabbled a couple of times so as to bring the high carbon in contact with the silicious slag. The above procedure may mean a little higher silicon than usual, and a hotter metal than would be desired. But it is believed that this is more satisfactory than the attending conditions when the bath is ored down, causing a greater slag burden and more unpleasant operation as well as greater wear on the furnace.

Some melters have considerable trouble in keeping their carbon up. On some heats they seem to lose more than on others. The ideal condition would be to incorporate the carbon as near as possible to the end of the heat. But when adding pig iron, the power must be on a sufficient time to thoroughly dissolve the amount necessary, which on a 6000-pound heat with a residual of .12 to .15 would mean 175 pounds, not allowing

any for loss. (Theoretically this would require about 2.9 per cent of the time of melting the heat or about 3 minutes.) Then again the power would be on after the manganese had been added to the bath. Therefore, during this period there is a chance for quite a variation in loss, one heat from another. Dipping the electrodes in the bath has proved satisfactory. We have adopted the following practice after determining the rate of carbon absorption by the bath from the electrodes. This was found practicable only with graphite electrodes, the rate of absorption being much more uniform than when using amorphous carbon electrodes. When the heat has reached the desired temperature, the power is turned off and two electrodes are immersed to a depth of 7 inches for 75 seconds (total elapsed time). With our regulation it takes 15 seconds for the electrodes to get down 7 inches and allowing 15 seconds for the upward trip, they remain stationary in the bath 45 seconds. This is slightly varied as indications warrant. Immediately the bath is rabbled well from both the spout and the door to thoroughly mix the metal. The power is then started and after 15 seconds the manganese is added. At the end of two minutes the power is taken off. The bath is again rabbled well and heat is ready to pour. Should higher carbon steel be needed, the electrodes are again immersed at the end for as long as is necessary. It is advisable to use three electrodes rather than hold any one over 100 seconds. The rate of absorption changes as the carbon is removed from the electrode.

To realize the full benefits of the above method, a fracture test should be examined just before adding the carbon to the steel. This may cause a decision to vary the length of time the electrodes are in the steel.

Problems of Manganese Control

Manganese control should be easy if the carbon and silicon are uniform. The following are pertinent points in manganese control:

1. Lower carbon than usual means slightly lower residual manganese.

2. Lower silicon than usual results in lower residual manganese.

3. When small lumps of ferromanganese are prevented from reaching the bath by a viscous slag, lower manganese will result.

4. Variation of the time that power is on after adding the ferromanganese will give a corresponding variation in manganese content.

5. The volume and nature of the slag affects the control.

The first and second causes should be apparent to the melter by the time manganese is to be added, and therefore he can increase his additions slightly. The third cause is preventable, as sacks or containers can be obtained for pieces that might be trapped in the slag. Such containers serve their purpose well. The fourth factor, time, must be watched with consistent accuracy—even to seconds. Two minutes is ample time. Any longer period means the enriching of the blanket of slag with good manganese from the steel. This brings us to the fifth point. Too much slag means more manganese to satisfy the greater capacity for absorption. For this reason slagging off is desirable earlier in the heat where an extra heavy amount of slag is noticed.

The temperature of the steel has a slight bearing on the control of all three elements. Exceedingly hot steel loses carbon and manganese, the manganese going into the slag and also volatilizing slightly.

Closer control of manganese can be obtained when adding all of the ferromanganese in the ladle, in small lumps, but the advisability of doing this is a matter on which there is a considerable difference of opinion.

Aspects of Control Problem

The sample for analysis is an important factor. It should be taken from a bar that will chill quickly in the sand, say 2 x 3 x 1 inches. The usual precautions for drilling samples should be kept in mind.

The test bar should be poured at the same time on each heat, preferably at the half-way mark. Tests made on samples

after regular time intervals on the same heat have shown a consistent change in analysis. This was most pronounced with the element manganese, particularly when the heats were hot, the decrease being as much as 8 points from the first to the last metal on some unusually hot heats.

Conclusion

After all is said and done, accurate control of analysis depends on the duplication of proper conditions, heat after heat, and where there is a departure, it then is dependent on the ability of the melter to gage conditions and the approximate analysis of bath and slag and to bring the charge back to the desired content.

In studying the subject of analysis control, the idea of the practice conducive to steel of the highest quality has constantly been given prime importance. Good analysis does not always mean good steel, but as a rule they are good partners.

Progress in Open-Hearth Process

By Willis McKee, Cleveland

Until the last couple of years, probably no process in the steelmaking industry progressed less since its introduction than the making of steel in the open-hearth furnace. From the building of the first successful furnace in this country a little more than 50 years ago there had been no basic change in open-hearth construction. It is true that during this time the units had become larger and more substantially built; the facilities for handling the materials to and from the furnaces had become much more satisfactory; improved valves had been invented; water cooled ports, doors, door frames and buckstays had been employed and slag line coolers had been installed; but the time of the making of the heat had remained approximately the same, the fuel economies had been improved but little and the operation of the furnace was no more under the control of the operator than a half century ago. The problem of satisfactory refractories is still unsolved, although this phase of the problem is now receiving most intensive study and consideration. The operation of the units is intermittent, shutdowns being necessitated every few weeks for repairs to the brick work.

About 10 years ago, a careful test was run at the Homestead works of the Carnegie Steel Co. to determine the heat balance of the open-hearth furnaces. The furnace used in the test made an average heat of 54.6 tons; natural gas was used as fuel. This test was run for seven or eight months. The results proved that the losses due to the temperature of the escaping gases, radiation, conduction and other causes amounted to 95.77 per cent of the heat units supplied by the combustion of the incoming fuel. This brings us to the startling conclusion that if we could eliminate all such losses that there would be only about 20 to 30 pounds of coal required per ton of steel produced. It is not to be expected that any such efficiency can be obtained, but it is time that careful thought be given to the

saving of our fuel supplies and to the lowering of the cost of steelmaking by their more economical use.

While blast furnace linings last from three to eight years, open-hearth units are not expected to remain in operation over four to five months. It is always expected that at least one furnace will be down in each shop for rebuilding and the other units will be frequently shut down for short periods for minor repairs.

In the last 10 years, the use of water-cooled devices has had a tendency to stabilize the operation of the furnaces, but excessive use of water of course decreases the thermal efficiency of the furnace, so that the use of such equipment must not be carried to excess. The use of waste heat boilers has materially decreased the heat losses but at a considerable cost of installation. The fact that the stack losses are great enough to justify the installation of waste heat boilers helps us to realize the inefficiency of the process.

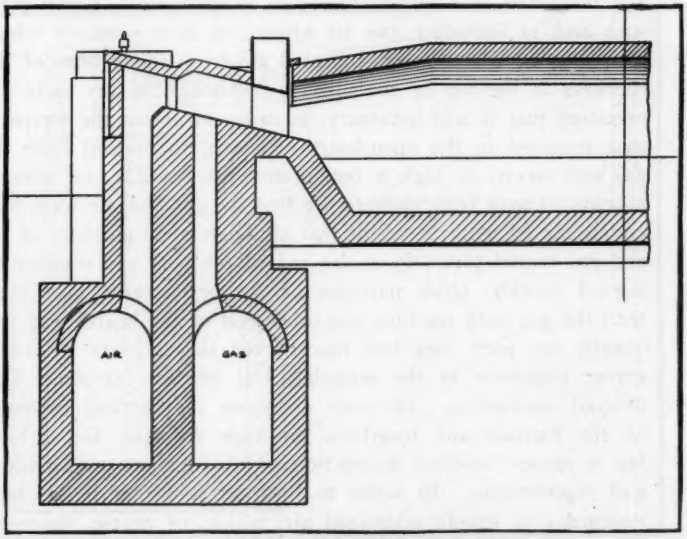


FIG. 1—SECTION THROUGH COMBINED PORT OF BLOW TORCH FURNACE

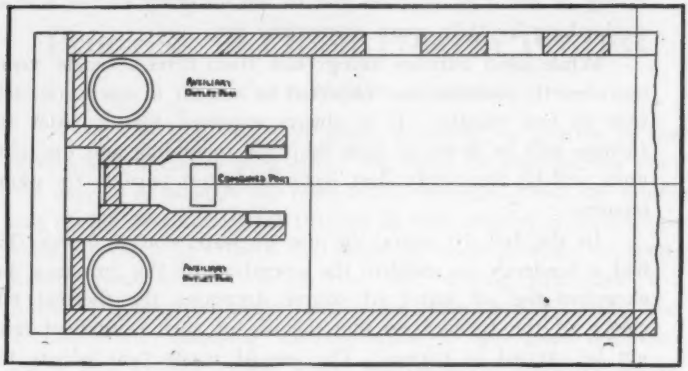


FIG. 2—HORIZONTAL SECTION SHOWING PORT ARRANGEMENT

The greatest cause of the low efficiency is imperfect or delayed combustion. It has been customary to introduce the gas into the hearth in a semicircular port at about ½ to 1-inch pressure and to introduce the air around it at a pressure which is created by the column of heated air from the bottom of the checkers to the top of the uptake. Although it was early appreciated that it was necessary, in order to obtain the temperature required in the open-hearth furnace, to preheat both the gas and air to as high a temperature as possible, no attempt appears to have been made to see that the gas and air were intimately mixed with the result that although some particles of air and gas mixed promptly at the end of the port and combustion started quickly, other particles of air never came in contact with the gas until reaching the other end of the hearth and frequently not until they had reached the slag pockets or regenerator chambers in the outgoing end of the furnace. This delayed combustion not only decreases the thermal efficiency of the furnace and lengthens the time required for a heat, but it causes needless destruction of the uptakes, slag pockets and regenerators. In order to insure combustion it has been customary to supply additional air, which, of course, decreases the thermal efficiency. In the test previously mentioned, it was found that 150 per cent excess air was actually being used. If

such excess is maintained while conducting a test, it is to be assumed that under normal conditions, even worse practice prevails.

Only about three years ago it was first proposed to mix the fuel and air before they entered the hearth of the furnace so as to obtain complete combustion promptly. This is an application of the Bunsen burner or blow torch principle which was invented some 65 years ago with the exception that the Bunsen burner insures against burning in the mixing chamber by having the velocity of the gases such that the flames cannot travel back into the mixing chamber. In an open-hearth furnace the temperature of the gases coming from the regenerators is so high that the flame is initiated as soon as the gases come in contact with each other. It is, therefore, necessary in order to use this principle to cause the gases to travel at such a velocity that there will not be enough combustion in the port to raise the temperature to such a point as to cause rapid destruction of the port.

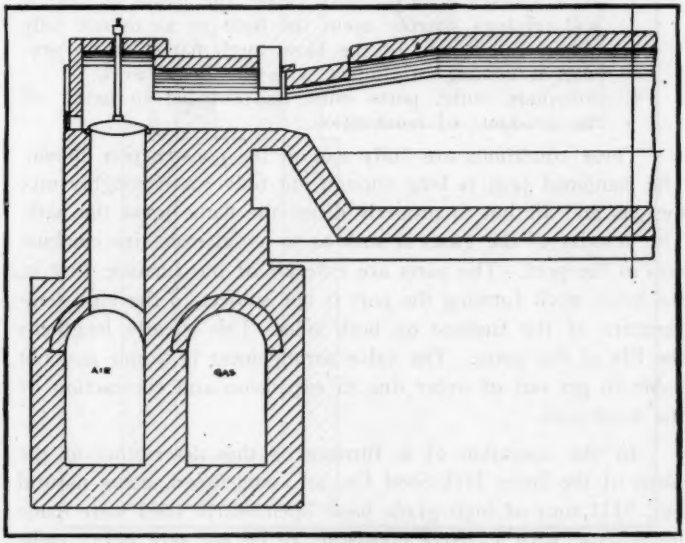


FIG. 3—SECTION THROUGH AUXILIARY OUTLET VALVE

Figs. 1, 2, 3, and 4 show the construction of the blow torch port similar to what has been used successfully at the plant of the Brier Hill Steel Co. The air and gas are introduced into the regenerators in the usual way except the air is under 2 or 3-inch pressure and then the air and gas are admitted into the same port from which they issue properly mixed, at a high velocity.

After a careful study of the requirements of a successful blow torch or Bunsen burner installation, it has been found that the following conditions must be met:

1. When using producer gas it is necessary to so introduce the air and gas that excessive gas house pressure will not be required. In other words, if over 1½-inch air pressure is used (and a higher pressure has been found desirable, it is necessary to aspirate the gas so that the proper amount of gas can be introduced without necessitating a gas house pressure in excess of 2 inches.
2. It is necessary to insure a perfect mixture of the gas and air before they issue from the port.
3. It is necessary to properly direct the flame so that it will impinge sharply upon the bath so as to not only obtain full benefit of the blow torch flame but to prevent it coming in contact with the brick work.
4. Adequate outlet ports must be provided to carry off the products of combustion.

These conditions are fully met in the construction shown. The combined port is long enough not only to thoroughly mix the gas and air but to properly direct the flame upon the bath. The velocity of the gases is such as to avoid excessive combustion in the port. The ports are exterior of the furnace, that is, the brick work forming the port is not subject to the high temperature of the furnace on both sides. This greatly lengthens the life of the ports. The valve arrangement is simple and not liable to get out of order due to expansion and contraction of the brickwork.

In the operation of a furnace of this description at the plant of the Brier Hill Steel Co. at Youngstown, using natural gas, 9111 tons of high grade basic open-hearth steel were made in 31 days, with a charge consisting of 65 per cent heavy melting scrap, 6 per cent cold pig iron and 29 per cent hot metal.

The best tonnage ever made in this shop on a furnace using ordinary method of construction was 6344 tons, and this record was made when using a mix of 45 per cent scrap and 55 per cent hot metal. The average monthly output per furnace of this shop operating on approximately 45 per cent scrap is 5000 tons per month.

On account of the short, sharp, blow torch flame the gases

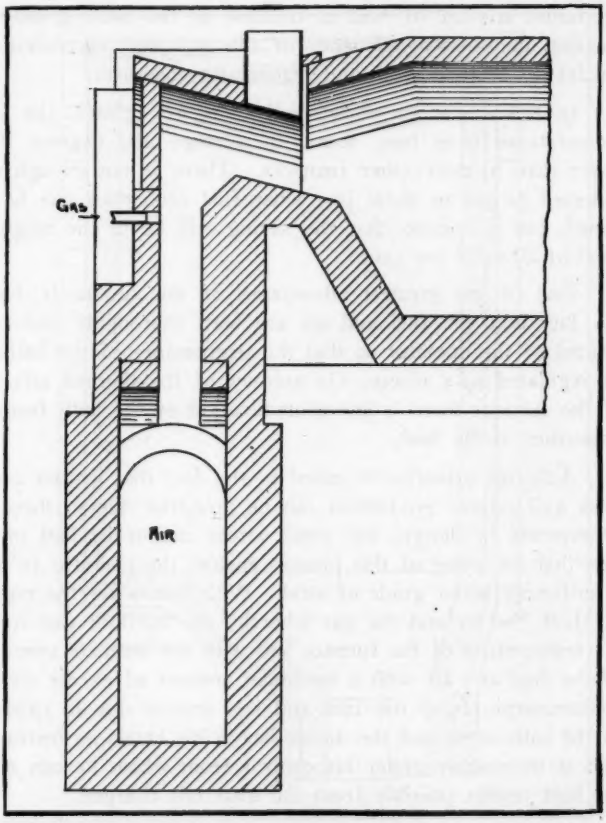


FIG. 4—SECTION THROUGH COMBINED PORT DESIGNED FOR COKE OVEN OR NATURAL GAS

attain their highest temperature and combustion is completed before they reach the middle of the hearth. From this point their temperature drops rapidly due to the radiation and transmission of heat to the bath, so that, notwithstanding the fact that the flame in this furnace is much hotter than in other furnaces, the temperature of the escaping gases in the downtakes and in the regenerator chambers is very considerably decreased. In other words, the combustion is completed so early that the maximum amount of heat is retained in the bath, greatly increasing the thermal efficiency of the unit and decreasing the repairs to the downtakes and regenerator chambers.

In practice at the Brier Hill Steel Co.'s plant, the stack temperatures have been found to average 300 degrees Fahr. lower than in their other furnaces. There is not enough data collected as yet to show just what fuel economies can be obtained, but it appears that the saving will be in the neighborhood of 20 to 25 per cent.

One of the greatest advantages of the system is due to the fact that the fuel and air are both thoroughly under the control of the operator so that the temperature of the bath can be regulated to a nicety. On account of the thermal efficiency of the furnace there is less contamination of the bath from the impurities in the fuel.

Although attention is called to the fact that greater economies and greater production can be procured due to these improvements in design, too much stress cannot be laid on the fact that the using of this process enables the operator to make a uniformly better grade of steel. With means for the regulating both the air and the gas whereby the operator can control the temperature of the furnace and with the intimate premixing of the fuel and air with a minimum amount of excess air, less contamination from the fuel and less trouble due to oxidation of the bath occur and the melter has in his hands an instrument that is thoroughly under his control from which he can obtain the best results possible from the materials charged.

Due to the fact that the charge is melted down so rapidly, a higher percentage of scrap can be used without the addition

of carbon, thus making possible the use of a much cheaper mix.

There are many refinements of the blow torch furnace which will be worked out, but the results so far obtained are so remarkable and the correctness of the principle involved has been so universally acknowledged as to insure its rapid introduction. This process of combustion has opened up quite a number of possibilities for the further improving of open-hearth con-

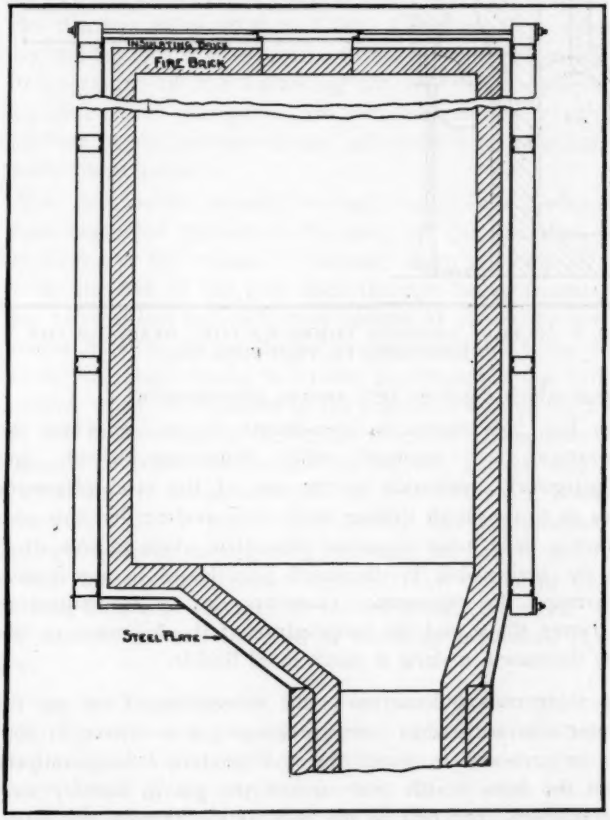


FIG. 5—STEEL ENCASED INSULATED REGENERATOR

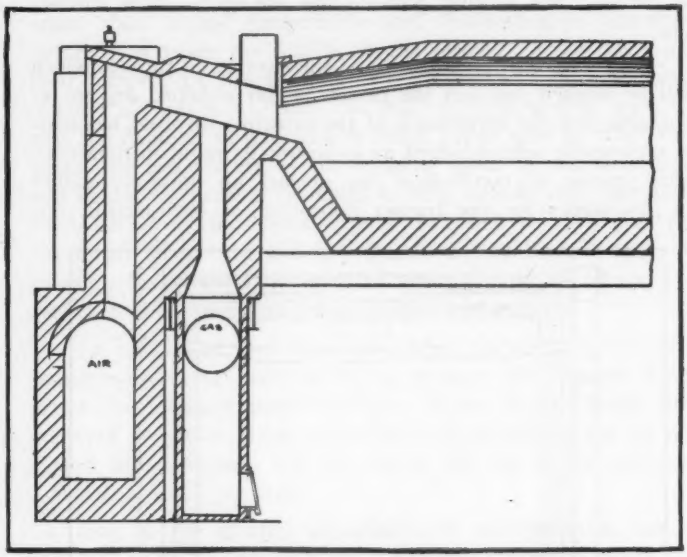


FIG. 6—SECTION THROUGH COMBINED PORT DESIGNED FOR UNREGENERATED PRODUCER GAS

struction which deserves very serious consideration.

In Fig. 5 is shown an open-hearth furnace in which the regenerators are encased with insulating bricks and steel platework. Inasmuch as the use of the steel platework enables us to use much thinner walls, it is evident that this construction is little more expensive than that which is now used, while the saving due to decreased heat losses is appreciable. Furthermore, the regenerator chambers can be maintained in much better shape and the temperature of the basement is materially decreased, making it much more livable.

A more radical departure is the eliminating of the gas regenerator chambers when using producer gas as shown in Fig. 6. It is proposed to locate the gas producers comparatively near to the open hearth and conduct the gas in suitable steel mains, properly insulated, to the ends of the furnace and introduce the gas into the air uptakes without any regeneration. This

practice becomes possible only by the use of the blow torch princple, where the air and gas thoroughly mix before they issue from the port so that the resultant temperature of the mixture is the only temperature that needs to be considered. Inasmuch as approximately 800 degrees Fahr. stack temperature is now obtained in a blow torch furnace, it is evident that the temperature of the gases escaping through the air checkers is much lower than those escaping through the gas regenerators, as the incoming gas cannot possibly lower the temperature of the gas checkers below 1050 to 1100. Therefore, it is evident that by making all the gases escape through the air regenerators the temperature of the incoming air will be considerably higher than when the gases are divided and the resultant temperature of the mixture of gas and air will be substantially the same as at present.

This construction appeals strongly to those to whom it has been suggested because it eliminates the gas loss that now occurs whenever the furnace is reversed when not only all the gas from the end of the port back through the generators to the gas valve is lost but with most designs of valves the gas in the mains back to the producers is exhausted by being connected to the stack during reversals. It eliminates the hydrocarbon loss which now occurs in the regenerators and the difficulties due to the clogging of the gas checkers. This construction greatly decreases the volume of the slag pockets and the heat losses due to radiation from the excessive space between the checkers and the ports. Structurally this construction is exceedingly desirable as it greatly decreases the cost of the furnace and shortens the distance required from center to center of furnace by five to 10 feet. It also eliminates the center wall in the slag pockets and the need of overhung brickwork in the uptake.

There is no question but that the transition through which the open hearth is now passing will so increase the capacity of existing units that there will be practically no construction of new open-hearth plants required to meet the demand for steel for a number of years, but one of the biggest problems incident to the introduction of the rapidly operated furnace will be to

get the raw material to the furnace and to handle the material on the casting side. New plants must be carefully laid out so as to eliminate as far as possible delays due to shop conditions and doubtless existing ones will need to be considerably altered and improved to take care of the additional materials to be handled.

Attention naturally has been attracted mostly to the basic open-hearth furnace, but inasmuch as the saving of time in the process is principally in melting down, at least equal increase in tonnage can be expected in acid furnaces.

While previous inventions in the open hearth have had for their object increasing the comfort of the operators and the decreasing of the shut downs and repairs to the furnace, the effects of this invention are so far reaching that it is difficult to appreciate the magnitude of the development. The principal advantages as have been outlined are

Better steel
Increased fuel economy
Greatly increased output
Longer life of the furnace
Possibility of using a higher percentage of scrap
Decreased plant cost for a given capacity.

By using unregenerated producer gas as proposed, it should be possible to obtain the following additional advantages:

Additional fuel economies
Greatly decreased cost of construction
Simpler construction.

No great invention is ever made that does not require considerable study and the careful co-operation of all interested before the full benefits of such invention can be obtained, so it will be necessary to have the hearty co-operation of engineers and operators before the maximum results are derived with the blow torch furnace However the correctness of the principle is so universally acknowledge and the results already obtained are so remarkable as to necessitate its rapid introduction.

Discussion—Progress in Open Hearth Process

R. A. BULL: I would like to ask what effect has been noticed on the life of the roof in the new construction described.

WILLIS MCKEE: It is rather surprising that as a rule the effect of the excessive temperature has been on the front and back walls and not on the roof. The combined port is so sloped that the gases do not get to the roof.

F. D. GLOSSER: I would like to ask if there has been any progress made along this line toward the operation of oil-burning furnaces and what he would suggest could be done with them.

W. MCKEE: Personally I do not know the details and progress of oil-burning furnaces. I believe that the same principle will apply, of getting the fuel and the air intimately mixed.

E. F. CONE: The importance of Mr. McKee's paper cannot be exaggerated. I think we are on the eve of wonderful developments in the open-hearth line, particularly in ingot production; and I cannot see why it will not apply to steel castings. The question of refractories is important, but not as important as people have tried to make out against this system. I think there are brick companies who can make a successful brick, that will stand considerably higher temperatures than what we have now.

The point that better steel is one result of the principles carried out in the new furnace is important. In the electric furnace, we can make a much higher grade of steel due to the higher temperature. It seems to me if we get a higher temperature in the open hearth, even though we do not have the reducing conditions that exist in the electric furnace, that is an argument for the use of the blow torch furnace.

The Past, Present and Future of Side-Blown Converters

By T. Levoz, Auxonne, Cote-d'Or, France

(*Translated from the French*)

At the autumn meeting of the Iron and Steel Institute in London in 1886 Sir Henry Bessemer read a paper giving an account of the various experiments made by him before finally constructing his bottom-blown converter as being, in his opinion, the most practical apparatus for the conversion of liquid pig iron into iron or steel.

Among the different types of apparatus described in his paper not once was there any mention of the blast being made to strike the surface or nearly at the surface of the pig iron bath. All the tuyere arrangements indicated insufflation of the air straight into the bulk of the molten metal, and under these conditions I am surprised that he was able to obtain conclusive results. It is quite true that in no instance did he mention what blast pressure he had available.

He drew attention, however, to the Clapp-Griffith patent of 1881 and pointed out that the terms of the application were practically identical with those of his patent of March, 1855, of which he submitted diagrams showing the arrangement of the appliances he had then recommended. In 1884, however, the writer employed the Clapp-Griffith apparatus at the Stenay Iron Works (France) and was thus in a position to ascertain that it was entirely different from the apparatus invented by Bessemer in 1855.

As a matter of fact Clapp and Griffith recommended a stationary apparatus (cupola type) in which the tuyeres, placed around the circumference of the crucible, injected the air at mid-depth of the bath; that is to say, if the depth of the bath of the crucible was 300 millimeters the tuyeres

Contributed through the courtesy of the Association Technique de Fonderie de France, 145 Rue de Faubourg, St. Denis, Paris, Jean Carles, l'Ingenieur Delegne.

were placed 150 millimeters from the surface of the bath, this arrangement necessitating an atmospheric pressure of 70 centimeters of mercury, whereas the Bessemer converters employed required a pressure of 1.25 to 1.50 atmospheres. Clapp and Griffith aimed to render possible smaller installations than those required by Bessemer, so as to facilitate the production of steel in works of average size. This enabled the apparatus to be employed with success in English tin plate plants. It was with the object of manufacturing thin plates that the Stenay Iron Works in 1884 installed one of these converters.

Our converter was installed by a representative of the manufacturers in October 1884, and in November the writer took over the manufacture, and placed it practically on an economic basis by increasing the capacity of the blowing engine. This modification enabled me to produce some remarkable soft and hard steels, but of irregular quality owing to the great superoxidation of the iron produced in the zone of the tuyeres.

The rare soft and hard steels owed their success to the automatic evacuation of the slag as fast as it was produced, and I am of the opinion that if we had used pig iron with less silicon the apparatus would have given better results.

The inventors of the Walrand-Delattre type converter had adopted the same system of blast insufflation as in the preceding apparatus but had made it movable like the Bessemer converters, which facilitated control of the processes of conversion. However, it was necessary to supress the tuyeres on the tilting side in order to render the control still more convenient.

This alteration, which was considered successful for the purpose of ensuring a control of the operation of blowing without causing superoxidation of the iron, brought about the graver disadvantage of an excessive burning of iron in the zone close to the tuyeres. This led to considerable slopping of metal and slag from the converter, and the operation did not really proceed satisfactorily until the surplus metal contained above the tuyeres had been evacuated.

The observance of this fact led me to establish the following principle, which has revolutionized all methods previously known of introducing the blast into the pig iron bath.

In 1885 the writer discovered—because of mobility of the converter on its trunnions—that it was necessary to begin the operation of conversion by introducing the blast at the surface of the bath; next, when desiliconization had been completed, that the apparatus should be inclined towards the tuyeres so as to increase the depth of the metal over the latter the operation of decarbonization being completed with 5 to 6 centimeters of metal above the axis of the tuyeres.

The atmospheric pressure then supplied by the blowing engine, varied between 20 and 25 centimeters of mercury, and this made possible a heat in 15 minutes instead of 30 minutes as formerly. The metal obtained was hotter and more fluid, and the yield of metal was 85 per cent, whereas it had before been only 75 per cent of the weight of pig iron placed in the converter. This result constituted a real economic development which attracted the attention of the metallurgical world to side-blown converters.

Robert then took out a patent for his converter with crucible of rectangular section, the tuyeres being placed on one of the larger sides of the rectangle. It did not succeed in giving good results until after it had been modified when it became known in the metallurgical world by the name of the Walrand-Delattre-Robert converter. It was adopted in several works, and it was only then that side-blown converters began to be of practical industrial account.

On the recommendation of Robert, I retained the flat face on the side of the tuyeres, the latter being inclined in the horizontal plane so as to produce a gyratory movement of the metal in the crucible, the section of which is D-shaped or, more accurately, in the form of a horseshoe. The drawing, Fig. 1, shows vertical sections and horizontal sections of this apparatus at the trunnions and tuyeres, respectively.

The wear of the lining, as in the preceding apparatus

took place along the dotted line. It will be noticed in the first diagram that the wear is almost nil to a height of 15 to 20 centimeters at the bottom of the crucible (the entire bath having a depth of 32 centimeters), while it is very marked in the zone of the tuyeres. This arises from the great superoxidation of the iron in this zone. These iron

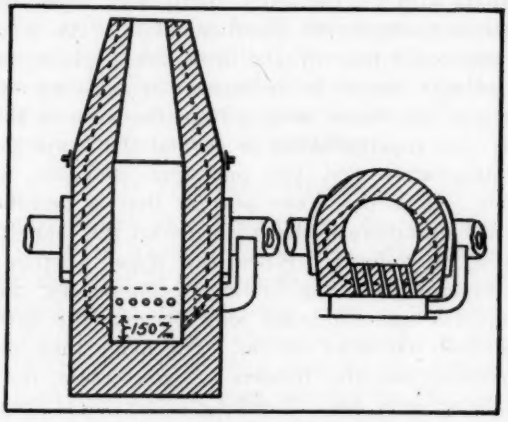


FIG. 1—VERTICAL AND HORIZONTAL SECTIONS OF CONVERTERS OF THE ROBERT AND TROPENAS TYPES. THE DOTTED LINES SHOW THE WEAR OF THE LINING AFTER 30 TO 40 HEATS

oxides, which do not act quickly enough as refining agents, attacked the lining at this point to form iron silicates which passed into the slag, rendering it very fluid.

An examination of the horizontal section shows, in accordance with the wear indicated by the dotted line, that the iron oxides did not reach the part opposite the tuyeres but remained in the worn portion, producing a whirling motion from bottom to top which in no way resembled the whirl of the gyratory movement. The latter, therefore, did not occur, whatever Robert might maintain to the contrary. The process of conversion in this apparatus may then be explained as follows:

At the outset there is a surface blast of the metal bath

in order to burn the silicon—and at the same time it unfortunately burns a good deal of iron also; forming slag highly charged with iron oxides and silicates.

The portion of the bath comprised within a height of 10 to 15 centimeters from and beneath the tuyeres is highly charged with iron oxides in the form of peroxides. The reactions with the carbonized parts then begin and this is the commencement of decarbonization. At a certain moment superoxidation of the iron takes place, causing intense boiling which is indicated by a very marked lengthening of the flame issuing from the nose of the converter. If this superoxidation is normal the flame subsides almost immediately and the operation proceeds with a short flame. It is the lower portion that is decarbonized owing to the difference in density between the refined metal and that to be refined. When the upper portion again becomes superoxidized the boiling recommences, and the flame lengthens and continues long because the bath contains practically no more carbon. The flame then shortens almost instantly and this finishes the conversion, the metal produced being very hot. Working under these conditions the converter enabled 60 to 65 heats to be made without the refractory lining being repaired.

The two breaks of the flame during decarbonization are thus explained, and this differentiates the nature of the side-blown process from that of the bottom-blown converter, showing at the same time the novelty of the principle discovered by me in 1885 as compared with that of Bessemer, who made no mention of the former in his paper.

If the superoxidation is abnormal it is due to the faulty application of my principles. If considerable quantities of iron oxides are formed in the zone above contact with the tuyeres and intense boiling is produced; the flame lengthens persistently, causing slopping of metal and slag; the flame then subsides suddenly, and this finishes the conversion with cold metal as the product. In this case there have not been two distinct breaks of the flame, because the

surplus iron oxides in the form of ferrous oxides have absorbed the greater part of the calories in their reduction, thus diminishing the duration of decarbonization but producing a cold metal unsuitable for casting in the molds. Working under these conditions the converter could accomplish only 30 to 40 heats.

From these observations it is clear that the arrangement of this apparatus was badly conceived; the flat face in conjunction with the direction given to the tuyeres was unfavorable to the gyratory movement, and this localized the refining zone in the bath, thus producing the irregularities found when the metal was produced.

The Tropenas Converter

Tropenas experimented with the construction of a converter which he thought to be new. He retained the flat face on the level of the tuyeres; the latter he arranged in two superimposed rows giving them a direction perpendicular to the axis of the converter passing through the trunnions in order to obviate the gyratory movement which he really believed to have been effected in the Walrand-Delattre-Robert apparatus; moreover he gave the crucible the form of a truncated cone so as to increase the bath depth below the tuyeres and thus permit the continuous injection of the blast above and at the surface of the metal bath. This, he maintained, had the advantageous effect of obviating the continual mixture of the metal with the slag during the conversion.

He advocated side blowing at the surface of the bath during the desiliconization and decarburization. It was by observing the behavior of the converters worked by his pupils that I found that the wear was much more pronounced and more rapid than in that of the preceding apparatus. The number of heats made with a new lining did not exceed 30 or 40 before repairs were necessary and consequently the crucible became larger between one pouring and another. This altered the conversion conditions from one pouring to another and had the direct result of producing a

very irregular metal with a conversion waste amounting to 20 to 25 per cent. The metal produced under these conditions appeared hot and liquid on coming from the converter, but immediately it was subjected to the action of the atmosphere it solidified on the surface of the ladle, forming a "skin" well known to specialists, which entirely prevented the pouring of small castings.

The writer took out a patent in 1893 for a device with a cylindrical crucible and tuyeres directed tangentially to a circle so that they should occupy a small arc of a circle in a horizontal position, in order to localize the action of the impressed blast while at the same time increasing the directive power so as to provoke the gyratory movement the attainment of which had previously been so greatly desired. As has already been seen, it is the wear of the refractory lining that best indicates the progress of conversion and purification in converters. In bottom-blown bessemer converters the lining is worn to a relatively small extent, because the iron oxides are well distributed throughout the mass and act as refining agents without attacking the lining. The bottom only wears away rapidly owing to the jumping of the metal.

It has been shown how irregular was the wear of the linings of the side-blown converters described above. On examining Fig. 2 which shows a transverse section and a horizontal section of my converter, it will be seen that the wear, as represented by the dotted lines, already indicates a greater regularity of working than in the previous types of apparatus.

There is no doubt that the arrangements adopted for the tuyeres enabled the blast jets to better convey the iron oxides, which acted more effectively as a purifying agent. In the upper zone, however, an excess still remained, although it was considerably diminished, as the bottom and the lower part of the crucible wear away instead of being recharged as in the preceding cases.

Here the oxidation of the combustible elements in the metal is effected more regularly from the zone of the

tuyeres as far as the center of the mass, where the iron oxides, forcibly formed, act as purifying agents. The portions of the bath comprised between *C* and *C'* (see Fig. 3) are less rapidly worked, and it is necessary to burn more iron to produce the boiling required to bring these portions of the bath into the general mass to be oxidized in their turn.

It should be noted also that the portion of the lining lying opposite the tuyeres, (Fig. 2) shows greater wear than in the apparatus previously mentioned. This is an almost certain proof that the gyratory movement takes place.

From this it may be concluded that the progress of conversion is already more regular in my converter and

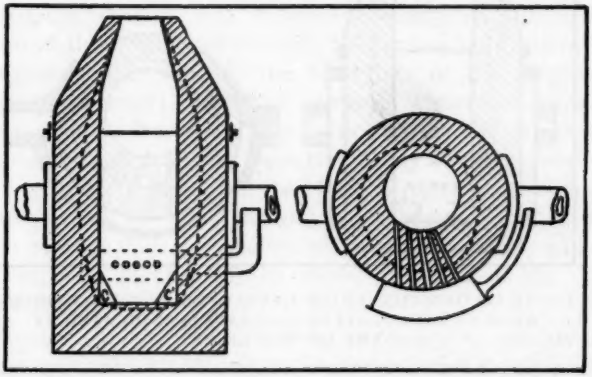


FIG. 2—SECTIONS OF THE FIRST CONVERTOR DEVELOPED BY THE AUTHOR. THE DOTTED LINES SHOW WEAR OF LINING AFTER 65 TO 80 HEATS

that it approximates to conversion by bottom-blown apparatus. The proof is that the lining stood 80 heats before the first repairs as compared with 30, 40 and 65 in the case of the other apparatus. This, then is an advance. The disadvantage of the rapid wear of the crucible, however, still exists, causing the blowing conditions to vary from day to day unless the precaution is taken to increase the weight of the charges in proportion to the increased capacity of the crucible.

In using this converter it was observed that the air was unable to expand sufficiently in the blast box to penetrate into the tuyeres, which caused a superoxidation of the iron at their nozzles. However, the capacity of the blast box of this converter was greater than that of the Walrand-Delattre-Robert and Tropenas converters, but this did not seem to be enough.

The writer then constructed another converter intended to obviate friction as much as possible by supressing the arc-bent pipes conducting the blast from the trunnions to the

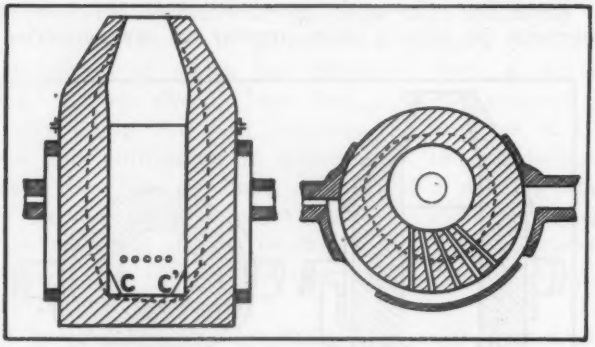


FIG. 3—THE SECOND CONVERTER DEVELOPED BY THE AUTHOR. THE WEAR OF LINING AFTER 130 HEATS IS INDICATED BY THE DOTTED LINES

blast box, as shown in Fig. 3. The hollow trunnion delivers the blast directly into the blast box which occupies the semi-periphery and the height of the cylindrical portion of the converter; the arrangement of the tuyeres and the lining remained the same. This modification of the blast box alone proved very advantageous, for it enabled me to obtain more uniform conversions. The wear of the lining and tuyeres was much less marked; a metal was obtained of uniform heat and homogeneous to a degree previously unknown; its iron oxides, completely reduced, did not attack the organic matter in the sand; the result being steel castings the "skin" of which was as smooth as that of

ordinary castings—a thing which had not hitherto been seen in the production of steel castings.

To all this was added the noteworthy advantage of the slow wear of the lining, which withstood 150 heats without repair as compared with 80 heats in the case of my previous converter, and to this the uniformity in working which I obtained was due.

We have not yet reached perfection, and much has yet to be done to enable side-blown converters to fulfill our expectations of them and particularly to produce on a large scale like bottom-blown converters.

The trials of 5 and 6-ton converters with acid and basic lining in 1888-89 and 1895 at the Angleur steel works in Belgium showed that it was necessary to reduce the section of the cylindrical crucible, to increase its depth while accentuating the force of the blast jets in the tangential direction. I would direct the attention of metallurgists to the very important point that with the side blast, as the air does not penetrate the mass completely as in the bottom-blown converter, there will be less nitrogen and occluded gas retained in the metal as well as less slag, which justifies me in saying that the quality of metal for sheets will be even superior to that of the steels produced in the open hearth furnace.

To accomplish this is will be necessary to obviate the defects normally attributed to converters and to do so the following points are essential:

1. To introduce the air into the tuyeres free from all humidity and steam;

2. To allow this air to expand before entering the tuyeres;

3. That this air, under sufficient pressure, shall be injected into the bath by the tuyeres suitably disposed so as to ensure the maximum combustion of the combustible elements in the metal without superoxidizing the iron;

4. In order to do this it is necessary that the crucible containing the pig iron bath shall be placed in such a manner

that the air issuing from the tuyeres shall be distributed uniformly in the bath so as to produce desiliconization without an excess of burnt iron, in order to bring about regular decarbonization without the boiling which is so harmful to the proper development of the operation and particularly to its perfectly accurate control.

The essential points of the new converter are shown in

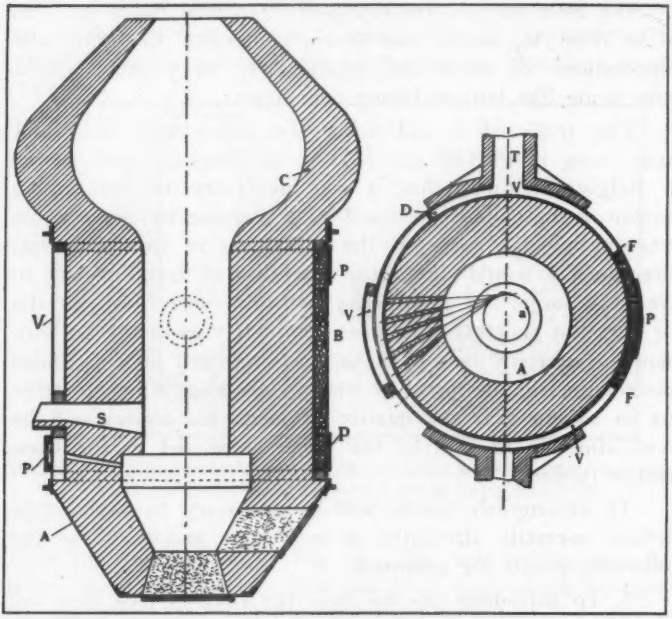


FIG. 4—THE NEW CONVERTER SHOWING DEPARTURES FROM CONVENTIONAL LINES

Fig. 4. The vertical section shows the crucible *A* in the form of a reversed truncated cone, the cylindrical portion *B* carrying the circular blast box *V* provided with the tuyere inspection door *P*. In addition there are two doors *P'* and *P''* for renewing the pumice stone soaked in sulphuric acid or other substances for drying the air; further, the slag spout *S* is for the purpose of evacuating the slag as fast

as it is formed during desiliconization, pouring being facilitated by the pasty consistency of the slag and the narrowing of the cylindrical part above the tuyeres. The upper dome-shaped portion *C* represents the pouring nose of the converter; it is dome shaped in order to retain the sloppings and cause them to fall back into the bath and also to receive the converted bath in one mass so that the deoxidizing additions may be well distributed.

The horizontal sections shows the two trunnions enabling the apparatus to be tipped in the same way as all converters. One of the trunnions *T* is hollow in order to admit the air at maximum pressure from the blowing engine and distribute it into the very large circular blast box where it expands. A partition *D* forces the blast to pass through the filter *FF;* containing the drying material, after which it enters into the tuyeres.

The essential mechanical parts of the apparatus having been clearly shown, it is desirable clearly to indicate its method of working in order that the maximum output may be obtained. The blast on coming from the blowing engine, at a pressure of 40 to 50 centimeters of mercury, enters the circular blast box directly through the hollow trunnion *T*. It there encounters the partition D which compels it to pass through the filter *FF*; the latter, which is formed with two perforated partitions, allows the blast to pass through the layer of pumice stone or other drying material (which should have great resistance in order not be carried off and stop up the tuyeres). The blast issues fom the filter completely dried, as the temperature prevailing in the blast box is sufficient to vaporize the water and facilitate its absorption by the pumice stone. Moreover, this air expands in the blast box and enters the tuyeres at a suitable pressure (30 centimeters of mercury) in order to prevent superoxidation of the iron. This is chiefly obviated by the tangential disposition of the tuyeres in conjunction with the truncated cone shape of the crucible which ensures the gyratory movement of the metal bath. The crucible's dimensions should be calculated so that the metal bath stands above the axis

of the tuyeres by 5 to 6 centimeters when the apparatus is vertical and the process of desiliconization is well assured. This is essential in order to ensure the evacuation of the slag through the slag spout, which is rendered easier by the contracted cylindrical portion which stands a few centimeters above the crucible.

These new and appropriate devices prevent super-oxidation of the iron and consequently make the wear of the lining very slight, and thus ensure uniformity in the process of the operation and the formation of compact slag which swells up very rapidly to be evacuated by the slag spout without carrying off any of the molten iron.

The decarburization therefore takes place without too violent boiling and the small amount of sloppings produced will be collected in the dome and fall back into the bath. The result is that the flame produced by the uniform combustion of the carbon issues from the nose with absolute regularity, its ascents being infrequent, thus rendering it possible to determine the progress of the operation much more accurately than in other converters known.

Report of Committee on Steel Foundry Standards

For the past several years the Steel Foundry Standards committee of this association has at intervals presented reports covering standards and technical information of interest to the foundry industry generally, and to the cast steel division specifically. The reports as submitted were in each case adopted by the cast steel sessions, meeting at time of convening of this association, and have become a part of our proceedings.

On reviewing the past activities of the committee it is now apparent that in some instances the committee has acted for the phase of industry which they represented without possibly having given cognizance to other allied industries whose interests in materials in question were as great if not greater, than the cast steel foundry industry. This situation may in a measure have been due to the committee not having been instructed to follow up and formally make the standards after the report had been adopted, with the result that our proceedings note only recommended standards.

All of the foregoing refers specifically to fire clay, nozzles, and sleeves and to graphite stoppers. Even if the committee had been instructed to follow up the adoption of their reports and formally set a standard for the phase of industry which they represent, it is a matter of conjecture as to how effective the activities of the committee might have been.

At the outset the committee understood that the plants of the rolling mill industry were the greatest consumers of stoppers, sleeves and nozzles, and to serve them alone there are sizes and shapes in countless numbers. Some individual steel foundry had their own particular designs. The majority of the cast steel foundrymen, however, used the designs of the rolling mill industry.

The service demands of the foundrymen, especially insofar as sleeves and nozzles are concerned are quite different and far

more exacting. The committee made an effort to so modify the designs as to meet the foundrymen's requirements and not to interfere with the demand of the rolling mill industry. With no formally adopted standard and a hesitancy on the part of the refractory manufacturers to conform to the wishes of the smaller consumer, the reports as adopted still remain in the main as recommended standards.

During the period of the war the ceramic division of the War Trade board made an effort to standardize nozzles, sleeves and stoppers. No definite standard was arrived at other than that the refractory manufacturers, acting independently, drew up a standard.

In view of the foregoing and no formal steel foundry standards being extant, it is the recommendation of this committee that the recommended standards be cancelled. It is further recommended that a committee be appointed to re-open the subjects in question and to collaborate with the American Engineering Standards committee to draft definite standards Although outside of the jurisdiction of the existing committee, it is suggested that any other commitees of the American Foundrymen's Association working on standards and specifications also co-operate with the American Engineering Standards committee.

The American Engineering Standards committee marks an epoch in American industrial development. Their efforts cover a wide range of activities and inasmuch as they function as a "national clearing house for engineering and industrial standardization and acts as the official channel of co-operation in international standardization and provides an engineering service on engineering and industrial service matters."

W. A. JANSSEN, *Chairman.*

Report of A. F. A. Committee on Specifications for Steel Castings

Your Committee on Specifications for Steel Castings which has been one of several standing committees that has existed for some time and which is directed to co-operate with the American Society for Testing Materials has held no meeting since the last convention of the American Foundrymen's association. Considerable correspondence has been carried on between the members due principally to the activities of the Joint Committee on Specifications for Carbon Steel Castings for Railroads, composed of members of the American Society for Testing Materials and the American Railway Association.

The joint committee referred to has spent more than two years in an extensive investigation for the purpose of establishing higher standards for steel castings for railroad use. Much of the work which has finally led to conclusions was performed by a subcommittee on tests, the members of which are entitled to a great deal of credit for establishing facts which were previously obscure. In this testing work and in the analysis of the test data, L. H. Fry, of the Standard Steel Works, took a very prominent and helpful part. J. C. Davis, of the American Steel Foundries, should have the thanks of the steel casting industry for his prominent participation in the negotiations which have consumed so much time.

It is unnecessary to refer to the various steps which have led up to the present status of this matter of specifications. As matters now stand, the joint committee representing the testing society and the railway association has reached an agreement which has been formally reported to Committee A-1 on Steel of the A. S. T. M. as one of the parent bodies. The same report will undoubtedly be soon referred to the proper body of the American Railway Association, if indeed this has not already been done. The A. S. T. M. committee on steel, which is a large one consisting of 142 members, has approved the specifi-

cations as recommended by the joint committee of the A. S. T. M. and the A. R. A. with very slight changes. The report of the A. S. T. M. committee A-1 on steel incorporating the specifications as agreed upon by the joint committee of the A. S. T. M. and A. R. A. and as slightly revised by the A. S. T. M. committee on steel, has been sent to all members of the A. S. T. M. by mail for study prior to the A. S. T. M. convention to be held during the week of June 25th at Atlantic City.*

The procedure at Atlantic City will be to present this report in which the proposed railroad specifications are included, for discussion. A rule of the A. S. T. M. requires that new standards or proposed amendments of existing standards shall be presented at an annual meeting and there voted upon. On a two-thirds vote of those voting revised or proposed new standards come under the designation of tentative standards, regarding which written discussions addressed to appropriate committees are invited. At the next annual meeting of the testing society following that at which tentative standards are favorably voted upon, such tentative standards are subject to amendment by a two-thirds vote of those voting. They may then be referred by a like vote to letter ballot of the society, in which case a two-thirds vote of those voting is required for adoption; or on the recommendation of the committee concerned, tentative standards may be continued in the form as originally printed or as amended, in which case the regulations referred to above apply at any succeeding annual meeting.

The procedure just outlined may for special reasons be modified according to an A. S. T. M. regulation which provides that the deferring for one or more years of adoption, may be waived by a nine-tenths vote of those voting at the annual meeting at which they are first presented. In that case the prescribed vote as to amendments, letter ballot, and adoption shall be observed.

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*The proposed specifications for carbon steel castings for railroads were adopted as tentative standards at the meeting of the A. S. T. M. held at Atlantic City, June 26-July 1, 1922.

It will be seen from this that except when waiver is deemed expedient by nine-tenths vote, new specifications such as are now under consideration cannot be adopted without holding for one year a position designated as "tentative;" and that the proposed specifications for railroad steel castings may by two-thirds vote at the forthcoming convention of the A. S. T. M. acquire a tentative status.

Before quoting in full the proposed new specifications it is worth while stating that in the large number of tests which were made to establish requirements for reasonable physical properties it was found impossible to place dependence upon any known instrument for determining the true elastic limit of cast steel. This was a disappointment to some members of the joint committee who had previously favored the Berry strain gage for determining the elasticity of steel. Mr. Fry has prepared a very interesting report for the testing society covering the test data analyzed by him for the joint committee. These data show conclusively that it is unwise at the present time to depend upon any of the known methods employed to determine what is called the elastic limit but that the yield point as shown by the drop of the beam, as stated by the committee "indicates a definite permanent set of the metal. Furthermore, the yield point, as evidenced by hundreds of carefully made tests, bears a sufficiently fixed relation to the ultimate strength of a given class of steel to make consistent its use as a basis for the design of the various forms comprised of cast steel." The agreement of the joint committee on this point has probably eliminated from future specifications for steel castings for some time to come, any requirement as to true elastic limit because of its lack of practical value.

The proposed tentative specifications of the A. S. T. M. for carbon steel castings for railroads are as follows:

Minimum Tension Test Requirements for Cast Steel
Current A. S. T. M. specifications for steel castings

Kind	Tensile Strength Pounds	Per Cent Elong.	Per Cent Reduct. Area
B—Soft	60000	22	30
B—Medium	70000	18	25
B—Hard	80000	15	20

Yield point for all Class B steels—45 per cent of tensile strength.

Proposed A. S. T. M. specifications for carbon steel castings for railroads.

	Grade A Annealed	Grade B Annealed	Grade A Unannealed
Yield point	29250 pounds	36000 pounds	29250 pounds
Tens. Str.	Not specified	Not specified	Not specified
Elongation	1,600,000 / Tens. Str.	1,600,000 / Tens. Str.	1,450,000 / Tens. Str.
not under	24%	22%	22%
Reduct. Area	2,600,000 / Tens. Str.	2,500,000 / Tens. Str.	2,250,000 / Tens. Str.
not under	35%	30%	30%

By using these formulae, tensile strength values as shown below would establish the minimum elongations and reductions indicated:

Grade A—Annealed			Grade B—Annealed		
Tens. Str.	Elong.	Reduct. Area	Tens. Str.	Elong.	Reduct. Area
58000	27.6	44.8	70000	22.8	35.7
59000	27.1	44.0	71000	22.5	35.2
60000	26.6	43.3	72000	22.2	34.7
61000	26.2	43.1	73000	22.0	34.2
62000	25.8	42.0	74000	22.0	33.8
63000	25.4	41.3	75000	22.0	33.3
64000	25.0	40.6	76000	22.0	32.9
65000	24.6	40.0	77000	22.0	32.5
66000	24.3	39.1	78000	22.0	32.1
67000	24.0	38.8	79000	22.0	31.6
68000	24.0	38.2	80000	22.0	31.2
69000	24.0	37.7	81000	22.0	30.9
70000	24.0	37.1	82000	22.0	30.5
71000	24.0	36.6	83000	22.0	30.1
72000	24.0	36.0	84000	22.0	30.0
73000	24.0	35.6	85000	22.0	30.0

It will be noted that the values proposed under the headings of "physical properties and tests" constitute a radical departure from present requirements. The ultimate tensile strength is eliminated as a minimum requirement but it must be ascertained in order that values for elongation and reduction of area may be calculated. For the convenience of the members of the A. F. A. to whom this report is presented, mimeographed tabulations have been circulated illustrating according to the formulae prescribed what values shall apply to steels recording tensile strengths covering a wide range. Reference to these figures will show that a steel pulling 60,000 pounds must have an elongation of 26.6 per cent and a reduction of area of 43.3 per cent; that a steel pulling 65,000 pounds must have an elongation of 24.6 per cent and a reduction of area of 40 per cent; that a steel pulling 70,000 pounds, if in Grade *A*, must have an elongation of 24 per cent and a reduction of area of 37.1 per cent; or

that a steel in grade *B* which may pull 70,000 pounds must have an elongation of 22.8 per cent and a reduction of area of 35.7 per cent; also that grade *B* steel pulling 75,000 pounds must have an elongation of 22 per cent and a reduction of 33.3 per cent; while a steel pulling 80,000 pounds must have an elongation of 22 per cent and a reduction of area of 31.2 per cent. It may be helpful to here refer to the present A. S. T. M. specifications for steel castings which have generally applied for railroad use. Three grades, soft, medium and hard, have been prescribed, the soft grade being required to show minima of 60,000 pounds tensile strength, 22 per cent elongation, and 30 per cent reduction of area. The medium grade is now required to show minima of 70,000 pounds tensile strength, 18 per cent elongation and 25 per cent reduction of area. The hard grade is now required to show minima of 80,000 pounds tensile strength, 15 per cent elongation and 20 per cent reduction of area.

It will be observed that whereas it has been satisfactory for a 60,000 pound steel to show an elongation of 22 per cent and a reduction of area of 30 per cent, the required elongations and reductions in percentage according to the proposed railroad specifications will be 21 per cent and 44 per cent greater, respectively. The hard grade of steel which now has required minima of 80,000 pounds tensile strength, 15 per cent elongation and 20 per cent reduction of area will according to the proposed railroad standards, have to show values respectively 46 per cent and 50 per cent in excess of present requirements for percentages of elongation and reduction of area.

The chemical requirements in the proposed railroad specifications are of particular interest at this time in view of the preliminary report which has been issued by authority of the joint committee on investigation of phosphorus and sulphur in steel, on the effect of sulphur in rivet steel. It will be observed that whereas for several recent years a maximum limit of .06 per cent has been allowable for phosphorus as well as for sulphur, according to the proposed railroad specifications, the maximum limit for each of these elements is established at .05 per cent. It will also be noted that whereas according to current specifications no maximum limit is imposed for manganese con-

tent, the proposed railroad specifications establish a maximum percentage for manganese at .85 per cent.

The chairman of your committee on specifications for steel castings happens to have held membership in his personal capacity on A. S. T. M. committee A-1 on steel. A. H. Jameson, member of your committee, is the delegated representative of the A. F. A. on the A. S. T. M. committee on steel. Consequently the members of your committee have had opportunity to keep in touch with the developments of this matter after reference of it to A. S. T. M. committee A-1.

It would not be appropriate for your committee to prophesy in this report what action will be taken at the forthcoming convention of the A. S. T. M. regarding these railroad specifications. That meeting will be open for affirmative and negative discussion by any who may be present as members of the testing society. It may be recalled that the A. F. A. holds membership as an association in the A. S. T. M. and that one member of your committee of specifications for steel castings is the proper representative for officially voicing any opinion which might be collectively reached by you now regarding this matter, when the testing society holds its annual meeting.

The developments in this matter of specifications for railroad castings have only lately reached a stage where any publicity could with propriety be given the proposed railroad specifications. It is mainly for that reason that your committee's report has not been previously distributed in pamphlet form to the members of the A. F. A. Indeed so little time has elapsed since agreement by the A. S. T. M. committee on steel that the members of your committee have not had an opportunity to agree among themselves as to recommendations to make to you concerning this matter, and concerning the future status of specifications for steel castings for general use. The function of your committee in this matter, therefore, is to submit pertinent information through the contact which has been maintained with the important developments that have occurred.

The steel producing members of the A. F. A. are doubtless familiar with the slight changes in the A. S. T. M. specifications

voted upon favorably at the convention of the testing society in June, 1921. These changes were given in detail in the first issue of the A. F. A. Bulletin published last September. The changes removed the maximum carbon limitation from Class *B* castings; established a maximum limit for phosphorus of .07 per cent for acid steel in Class *A*, and .06 per cent for acid steel in Class *B;* prescribed a maximum limit for phosphorus of .06 per cent for basic steel in Class *A* and of .05 per cent for basic steel in Class *B*. The maximum sulphur limit was removed from Class *A* castings and was set at .06 per cent for Class *B* castings.

It may be recalled that Class *A* includes castings for which no physical requirements are specified while Class *B* includes those of the character just mentioned of hard, medium and soft grades.

It should be understood that the adoption of the proposed railroad specifications would not automatically nullify the present A. S. T. M. specifications for steel castings that lie outside the designation of carbon steel castings for railroads. The application of the proposed railroad specifications would simply inaugurate a new standard for a separate classification. No action has been taken by the A. S. T. M. sub-committee on specifications for steel castings to recommend at the forthcoming convention of the testing society any changes to apply to the general run of steel castings.

A matter which is not covered in the proposed railroad specifications but which is of distinct interest to steel founders is that of the proposed recommended practice for heat treatment of carbon steel castings which will be submitted to the testing society at its June convention this year.

It may be explained that the present recommended practice covers four ranges of carbon and accordingly four annealing temperatures. The new practice recommended covers only three of these. The proposed annealing temperature for low carbon steel is 900 degrees Cent. or 1652 degrees Fahr., whereas the present recommended practice for steel up to .16 per cent carbon calls for 925 degrees Cent. or 1677 degrees Fahr. The changes in temperature are very slight and were apparently con-

sidered advisable in order to establish three classifications instead of four as at present.

No A. F. A. representative has ex-officio held membership on the A. S. T. M. committee on the heat treatment of iron and steel which is sponsor for the proposed recommended practice for the heat treatment of carbon steel castings.

It should be of interest to steel casting manufacturers to know that the A. S. T. M. committee on malleable castings has recommended to the testing society modification of specifications for malleable castings, increasing the tensile strength from 45,000 pounds to 50,000 pounds and increasing the percentage of elongation in two inches from 7.5 per cent to 10 per cent.

At the June convention of the testing society tentative methods of chemical analysis of plain and alloy steels will be proposed by the committee on steel. Much consideration has been given this matter by the sub-committee to which it was delegated and it is hoped that the consideration of the proposed methods which were distributed in pamphlet form to the members of the A. S. T. M. late in May will result in benefit to steel founders in general.

Some correspondence has passed back and forth between the members of your committee and between its chairman and the chairman of the A. S. T. M. committee on cast iron and finished castings, regarding specifications for foundry pig iron. The A. S. T. M. committee invited our criticisms of proposed specifications for foundry pig iron in so far as such specifications relate to the steel foundry industry. After your chairman had ascertained the view of his associate on your committee regarding this matter, he advised the chairman of A. S. T. M. committee A-3 regarding these views in order that, if possible, these comments might aid in the intelligent preparation of specifications for pig iron for steel foundry use. Your committee is not informed as to further developments regarding this matter which will doubtless come up for discussion at the annual meeting of the testing society in June. It may be appropriately stated in brief that variations in the chemical properties of pig iron as at first proposed seemed excessive to your committee. An allowance of .25 per cent above and below for silicon; one of

.20 per cent above and below for manganese, and one of .15 per cent above and below for phosphorus had been suggested; while at the same time proposing that the sulphur content should not exceed nor the total carbon be less than the percentage stated in the pig iron contract.

It was pointed out to the A. S. T. M. committee by your committee that many steel foundries prefer to secure pig iron carrying as high a percentage of manganese as may be obtained but that they would not want to give much allowance downward. Criticism of any greater allowance for phosphorus than for sulphur was quoted to the A. S. T. M. committee.

It is believed that the pig iron specifications are not now in suitable shape for more exhaustive mention in this report.

The committee will appreciate suggestions looking to its future usefulness to the members of the A. F. A.

Respectfully submitted:

John H. Hall
W. C. Hamilton
A. H. Jameson
J. B. Nordholt
R. A. Bull, *Chairman*

The Manufacture and Properties of Refractories for Air Furnaces

By C. E. Bales, *Louisville, Ky.*

Although the subject of refractories for air furnaces has been given comparatively little study, it is now realized that it is exceedingly important and problems are being investigated from a great many different angles. During this period of deflation, it behooves every foundryman to study his refractories requirements and to know that he is getting material that will give him maximum service.

Most fire brick manufacturers are constantly endeavoring to improve their products and it is obvious that the few who are content to continue with the old "rule of thumb" processes will eventually fall by the wayside. This would be a blessing for the whole fire brick industry as such companies frequently quote prices that cannot be met by the manufacturer operating on a scientific basis and the result is, the foundryman often receives refractories of inferior quality that have to be replaced after three or four heats.

It costs a great deal to maintain chemical and physical laboratories, but the fire brick manufacturer believes that if a product can be made to give 30 heats instead of 20, it will be worth more to the foundryman.

The manufacture of bung brick is almost a specialty in itself and very few concerns make material that is really deserving of the name "bung brick." The writer has seen some so called "special bung brick" that had to be replaced after two heats.

Occasionally fire brick fail to give the service ordinarily received from them. Sometimes it is the fault of the fire brick, and, at other times, it is due to improper installation or furnace design, but there are also some failures that cannot be solved at all. These latter are embarrassing to the investigator and endless confusion occurs, because the foundryman thinks they

are the fault of the fire brick and the fire brick manufacturer thinks they are due to improper use.

All manufacturers of fire brick are desirous of overcoming these premature failures and it is believed that if a more intimate relationship existed between the foundryman and the fire brick man, the latter would be in a better position to furnish material that would give the highest possible service. It is hoped that this paper will give the foundryman some idea as to the problems confronting the fire brick maker and that it will help to establish this relationship for better service.

The History of Fire Brick

It would be difficult to determine when and where the first fire brick were made, but it is known that the mediaeval alchemist was adept in making crucibles, retorts and small furnaces. In the fifteenth century, considerable progress was made in the metallurgical and ceramic industries and this was made possible by the use of crucibles and furnaces made of heat resisting materials. As clay is the most common and widespread substance capable of resisting heat, it seems that mediaeval man would undoubtedly have known something about its properties and would have used it in lining his crude furnaces. A study of the ancient iron furnaces shows that they were lined with fire clay and reinforced by a backing of stone blocks.

The first fire brick produced in the United States were probably made in New Jersey in 1812, but there is no record as to the location of the original plant. In 1825, however, a plant was established at Woodbridge, N. J., and a few years later the industry spread to Ohio, Pennsylvania and Maryland.

In 1842 James Glover discovered a deposit of high grade fire clay at Bolivar, Pa. He erected a small plant and the brick manufactured by him were of such excellent quality, that they soon earned a good reputation with the furnacemen of Pittsburgh. A few years later, the manufacture of fire brick was started in Missouri and, although the industry developed gradually, it is now one of the foremost industries of the state.

Fire clay was mined in Lewis county, Kentucky, in 1871

and shipped to fire brick manufacturers in Cincinnati, but the industry in Kentucky did not amount to much until in the early eighties. In 1870, Messrs. K. B. Grahn, S. Eifort and J. Staughton, principals of the Tygart Valley Iron Co., bought 10,000 acres of land in the vicinity of Olive Hill, Ky. They had planned to erect iron-furnaces to smelt the local ores, but the project had to be abandoned, as the projected division of the Chesapeake & Ohio railroad through this region was

FIG. 1—THE ENTRANCE TO A FIRE CLAY MINE AT GRAHN, KY.

not completed until 1883. The land then was divided; Mr. Grahn took his allotment in the vicinity of what is now Grahn Station; Mr. Eifort took that part in the vicinity of Olive Hill; and Mr. Staughton's allotment was west of Olive Hill. Shortly after this, Mr. Eifort opened up a fire clay mine on his property and shipped the raw material to various points in Pennsylvania and Ohio. Its real value was recognized at once and there was a spirited demand for Kentucky clays.

About this time Mr. Grahn also began shipping considerable fire clay, but in 1889 he erected a plant in Louisville, to manufacture high grade fire brick from Carter county clay.

Mr. Eifort sold his land to the Olive Hill Fire Brick Co., and in 1895 they erected a plant at Olive Hill.

Occurrence of Fire Clays

Large deposits of the best natural fire clays in the world occur in Kentucky, Ohio, Pennsylvania, Missouri and New Jersey. In New Jersey the clay is of Cretaceous age, while in the other states named, it is of Carboniferous age. The Carboniferous fire clays are of three types: Flint or nonplastic, semiplastic, and plastic. The first two types are extremely refractory, but as they are practically nonplastic, it is necessary to mix them with some other clay that has good bonding power, although it may not be as refractory.

Some of the flint clay contains a high percentage of alumina. In Kentucky clay, this is due to the presence of gibbsite, while in Missouri it is due to the mineral diaspore.

In Kentucky the flint clays are usually associated with a sandstone, known as the Pottsville conglomerate and the clay varies in thickness from a fraction of an inch to 30 feet. Five feet is a good workable thickness.

Mining of Fire Clay

Before a mine is developed, it is customary to determine the area of the clay bed and to subject the material to certain chemical and physical tests. The sample is best obtained by the diamond core drill, but it is also necessary to examine all outcrops of the clay that may occur in gullies or in the beds of springs.

The core from the drill will show the exact thickness of the overburden and the clay deposit. It will generally indicate the quality of the clay and will show fairly well whether the deposit is wet or dry. Samples of the core are analyzed and the data thus obtained, determine the commercial value of the clay.

The method of mining depends upon the amount and character of the material overlying the clay deposit. Some beds of high grade clay occur rather close to the surface and it is possible to strip off the overburden with a scraper or steam shovel and then blast out the hard clay.

In some states, fire clay occurs at such depths below the surface that it is impracticable to mine it by stripping, but it may be mined by digging a pit or shaft to the deposit and then working it by means of tunnels.

The fire clay mines of northeastern Kentucky, one of which is shown in Fig. 1, are all drift mines. This is due to the fact that the overburden is so thick that it is impossible to remove it. Drift mines are operated by driving a tunnel or main entry through the entire clay deposit and branching off with cross entries, which, in turn, are branched off into rooms. The clay is hard and it is necessary to blast it with black powder. The roof of the mine is occasionally supported by heavy timbers, but usually the roof is of such material that any support, other than the clay pillars, is unnecessary.

The clay is transported to the plant either by electric motors or mules. If the plant is located at a great distance from the mine, it is more economical to use a steam locomotive.

Grinding In Wet Pans

When the clay is received at the fire brick plant it is either stored in large piles and allowed to weather, or it is coarsely ground and the crushed material conveyed to elevated bins. Each bin has an opening in the bottom from which the clay can be withdrawn as desired.

As some clay is devoid of plasticity, it is necessary to mix it with clay that is plastic, to bind the particles of flint clay together. Burnt clay, known as calcine or grog, is used in fire brick mixtures to reduce contraction, to make the product more porous and to make brick that will resist spalling.

After measuring out definite proportions of flint clay, plastic clay and calcine, the mixture is transferred to a wet pan when the necessary amount of water is added. It is then ground until it is of the proper consistency.

A wet pan, one of which is shown in Fig. 2, is about 8 feet in diameter with a side rim 12 inches high. The pan bottom is fastened to a vertical shaft which is revolved by an overhead crown wheel and pinion. The lower end of the vertical shaft rests in a step bearing. A false bottom of chilled iron

is placed on the pan bottom and this acts as the grinding surface. Around the vertical shaft is placed a horizontal shaft on which two crusher rolls are mounted, the ends of the shaft extending into the pan frame. These rolls, weighing about 8000 pounds each, are turned by being in contact with the revolving pan bottom and the clay is directed under the rolls by means of suspended scrapers. Some wet pans are equipped with emptiers which greatly increase their capacity.

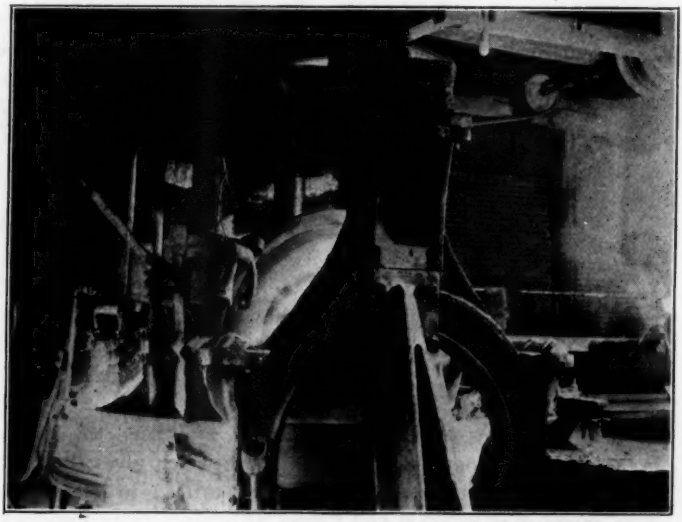

FIG. 2—A WET PAN FOR GRINDING FIRE CLAY

When the clay mixture has been ground to the proper fineness, a lever is pulled, which lowers the emptier into the pan. This forces the mud over the pan rim onto a small car and it is then pushed to the molding tables.

In making fire brick for malleable iron furnaces a great deal of care must be exercised in the grinding process, as some parts of a furnace require fine grained brick, while in other parts, coarse grained brick give the best service.

A dry pan is similar to a wet pan except that it is some-

what larger in diameter and its bottom, instead of being solid is filled with perforations 1/8 to 1/4 inch wide and 4 1/2 inches long.

The clay, being directed under heavy iron rolls by suspended scrapers, is crushed and the fine particles drop through the perforated bottom. From here the clay is conveyed by cups attached to an endless belt, to elevated bins for future use, or to a tower where it is prepared for dry pressed brick.

Molding the Fire Brick

Molds made of white pine are commonly used, but in some instances it is necessary to use harder woods to resist the cutting action of the hard particles of clay and calcine in the mud. If harder material was not used, the size of the mold would be increased and the resultant brick would be larger than the specifications called for, thus necessitating some chipping, which is always a costly process.

After sprinkling a thin layer of sharp sand in the mold, a piece of fire clay mud, slightly larger than the desired brick, is placed in the mold, pressed down well with the hands, and bumped on a heavy table. This is rather rough treatment for soft wood molds but it is necessary in order to fill out the mold. The excess mud is cut off with a wire and returned to the molding table. A smooth stick or slicker, moistened with water is then drawn across the top of the mold, which gives the brick a clean, smooth surface. The mold is carried to the drying floor where it is inverted and gently withdrawn from the brick.

In the molding of roof brick which have to be repressed, so much care in the preliminary molding is unnecessary, but this will be discussed under the "Manufacture of Bung Brick."

Drying the Molded Clay

As the freshly molded brick contain a great deal of water and are easily deformed, it is necessary that they be thoroughly dried before being placed in the kilns.

Fire brick are dried, either on heated floors or in tunnels, A drying floor, as shown in Fig. 3, is made of brick or tile, beneath which is a series of pipes carrying live steam. This

gives the floor a uniform temperature and the water in the brick is gradually expelled. A fan blows warm air over the top of the brick and this not only helps to drive out the water, but it reduces the humidity of the atmosphere in the dry house. This latter, is an important factor because, if the air was not kept in motion, a point would finally be reached where the air would be saturated with water vapor and there would be as much precipitation on top of the brick as there was evaporation from the bottom. Three days are required to dry a standard size fire brick.

Not so many years ago fire brick were dried by the hot

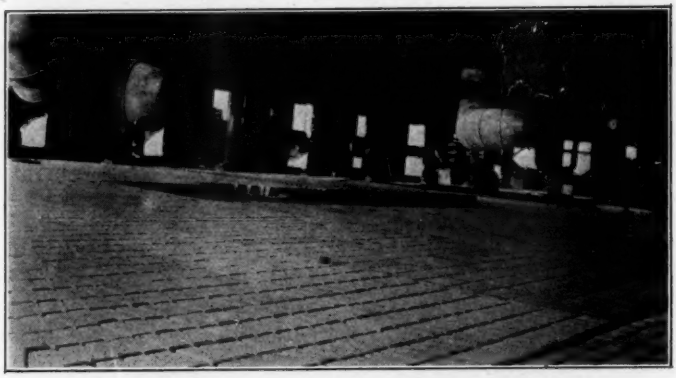

FIG. 3—A DRYING FLOOR WHERE BRICK ARE DRIED

gases derived from the combustion of coal. Instead of having steam pipes beneath the brick floor, flues ran the entire length of the shed, the fire boxes being at one end and the high stack at the other end. In this method the heat distribution was unequal, some parts of the floor being hot, while other parts would be comparatively cool.

Tunnel drying is undoubtedly the most economical, because the temperature and humidity can be easily controlled and it is possible to utilize the waste heat from the kilns. In this method of drying, the brick are stacked on iron cars, pushed in one end of the tunnel and gradually moved through to the other

end and then they are ready to be placed in the kilns. The temperature maintained in the tunnels is usually about 250 degrees Fahr. and it takes two days to complete the drying.

Most of the hygroscopic water is removed by this drying process, but the water chemically combined with the clay is not driven out until a temperature of about 1000 degrees Fahr. is reached.

Setting Brick in the Kilns

A great deal of skill is required in placing the green brick in the kilns. They must be placed far enough apart to permit the hot gases to pass through quickly, but they must be close enough so as to not reduce the capacity of the kiln. The brick are usually placed on their edges and a thin layer of white sand sprinkled between each layer to prevent sticking together when they become hot. About 50,000 brick are placed in a kiln. After the kiln has been filled the fire brick doors are put up and they are covered over with a mud made of fire clay and sand. The cooling holes in the crown are also closed and the kiln is ready to be fired.

Burning Fire Brick

Several types of kilns are used in burning fire brick, but probably the most common is the intermittent, round, downdraft kiln. This kiln, illustrated in Fig. 4, is about 26 feet in diameter and 12 feet high. The stack, which is located in the center of the kiln, is 3 feet in diameter and 28 feet high. Each kiln has 14 fire boxes in which slanting grate bars are used. The kiln floor is made of fire brick of such shape that when one is placed against the other there is a space of one-half of an inch between them. Beneath the floor, there is a series of flues which connect up with the stack. In mediaeval times, wood was used for burning refractories and later on, charcoal and coke, but at present, coal and natural gas are the most important fuels. In the future, producer gas and fuel oil no doubt will be used extensively in burning refractories.

Burning is one of the most important stages in the manufacture of fire brick and the kiln fireman can either produce

a kiln of good brick or he can make a worthless product. The burning process is divided into three periods: Dehydration or water smoking period; oxidation period, and vitrification period.

At first only a few lumps of burning coal are placed in each fire box, but gradually more coal is added until there is a small fire in each pocket. During the watersmoking period it is necessary that the heat be raised slowly in order to completely expel all hygroscopic or free water, in the brick. Water vapor can be seen issuing from the stack, and if the fires have been built up properly all the uncombined water will have been

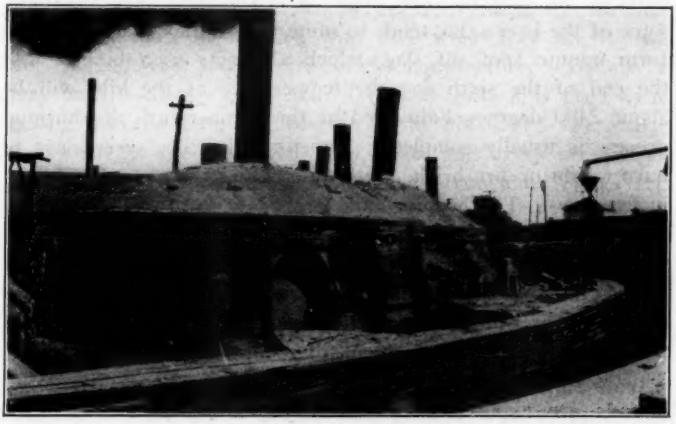

FIG. 4—A FIRE BRICK KILN

driven out by the end of the third day. The kiln temperature at this period is about 900 degrees Fahr.

A large excess of oxygen is needed during this period to unite with the carbon of the fuel, because carbon in the form of soot has a tendency to stick to damp brick and unless the kilnman is careful, so much soot may be deposited between the brick that the burning time will be almost twice what it would be normally.

On the fourth day the oxidation period begins. At the end of the fourth day the kilns are fired every hour instead of

every two hours. During this period the chemically combined water is driven off; ferrous iron is oxidized to the ferric condition; calcium and magnesium carbonate, if present, are broken up into carbon dioxide and calcium and magnesium oxides, respectively. If carbonaceous matter is present in the clay it will be converted into carbon dioxide. The brick begin to shrink and harden somewhat, but they are too soft to be used in furnaces. The temperature at the end of the fifth day is about 1900 degrees Fahr.

On the sixth day the vitrification period begins. The small amount of alkalies in the clay fuses and helps to bind the particles of infusible clay together. The lime, magnesia and some of the iron oxide tends to unite with the excess of silica to form minute spots of slag, which also acts as a binder. At the end of the sixth day the temperature of the kiln will be about 2400 degrees Fahr. and at this temperature the burning process is usually complete. Sometimes it takes seven days to burn a kiln of fire brick, but occasionally a kiln can be burned in five days. The burning time depends a great deal upon how dry the brick are when placed in the kiln and also upon climatic conditions.

A few years ago, nine to 12 days were required to burn a kiln of fire brick, but it has been proven conclusively that the longer fire brick are burned, the poorer their quality will be. This is due to the fact that when brick containing iron compounds are exposed to a smoky flame, the iron is reduced from the ferric to the ferrous condition and it then unites with the excess of silica to form ferrous silicate, a very fusible slag. The longer fire brick are exposed to heat, the more dense they become and consequently their resistance to spalling is greatly reduced. It is the aim of the fire brick manufacturer to burn a kiln of fire brick in six days and to have a large amount of oxygen passing through the kiln to prevent any reducing action.

It requires one ton of high grade coal to burn one thousand fire brick. The kiln temperatures are controlled by pyrometers, Seger cones or by observing the color of the heated brick through a peep hole in the kiln door.

When the burning process has been completed a few of the door brick are taken down and the cooling holes in the crown are opened. The kiln is allowed to cool in this manner for about 12 hours and then about half of each door is taken down. The heat is either allowed to go to waste or air is blown through the kiln and the heated air piped to the drying tunnels.

The kiln must not be cooled too quickly as the hot brick when suddenly cooled, crack and scale badly and their resistance to crushing is greatly reduced. Three days are required to completely cool a kiln.

Some types of fire brick are exceedingly friable and for this reason they must be handled with care when they are loaded into railroad cars. The fire brick manufacturer expends a great deal of money every year for straw, which is used as a packing material and this prevents undue breakage. The sharp corners of the brick are also kept intact and every precaution is exercised to insure the car reaching the consumer in perfect condition.

The Manufacture of Bung Brick

Three things are essential in the manufacture of fire brick for use in the roof of an air furnace. They are: The highest grade clay, scientific supervision, and skilled labor.

After selecting semiplastic and flint clays they are mixed with the highest grade calcine and ground with considerable water in a wet pan until a soft, coarse grained mud is obtained. The mud is withdrawn from the pan and conveyed to the molders where it is shaped in wooden molds and placed on the heated floor until partially dried.

The brick are allowed to dry for about five hours and by this time they are sufficiently firm to permit handling, but they are not too hard to prevent reshaping. These brick are then pressed in small hand presses and again placed on the heated floor until they are completely dried. This pressing gives the brick the desired shape, produces sharp corners, increases its mechanical strength and puts any necessary name or brand on the brick.

It has been thought by some fire brick men that repressing of hand made brick did more harm than good, due to the breaking of the original bond, but experiments have shown that such is not the case, unless the brick have been dried too long.

When the brick have become bone dry they are placed in the middle of the kiln where they are given a medium burn, the final temperature being about 2300 degrees Fahr.

The Manufacture of Semi-Dry-Pressed Brick

The name "dry-pressed" is somewhat of a misnomer as the brick really contain about 8 per cent of uncombined water, but this in no way detracts from the excellent properties which this type of brick possesses.

High grade semi-plastic clay mixed with about 15 per cent of plastic is ground in a dry pan with just enough water to prevent too much of the clay from getting into the air as dust. The crushed material is conveyed by cups attached to an endless belt, to a rectangular screen with piano wires, one-twelfth of an inch apart. The fine particles drop into a mixer, while the coarse particles are returned to the dry pan.

A little water is added to the fire clay in an English-style mixer and a series of revolving knives completely mixes the batch and keeps it moving until it drops into the storage bin.

A dry-pressed brick machine, one of which is shown in Fig. 5, consists essentially of a molding machine and a repressing machine. The molding machine consists of a heavy frame with a delivery table about three feet above the ground and a press box sunk into the rear of it. A chute connects the charger with the storage bin and this forms a framework which slides back and forth over the molds. The charger is filled on the backward stroke and allows the clay to fall into the mold box on its forward stroke. A plunger drops for just an instant, driving the clay into the molds and is then raised. As the charger recedes to be refilled the plunger drops again and the action of cams presses it down upon the clay with a pressure of about 800 pounds per square inch. Two brick are moulded at a time.

The brick are then passed to the repress where they are

subjected to a pressure of about 1000 pounds per square inch. The repress mold top as well as the bottom, is steam heated to prevent the adherence of clay.

This repressing makes the brick more compact, gives it greater strength, makes sharp edges and puts a brand on the brick. The brick may be placed directly in the kiln without preliminary drying and they are burned hard at 2400 degrees Fahr. Brick of this type are ideal for side walls of air furnaces.

Properties of Fire Clay

Fire clay is essentially an aluminum silicate and its theoretical composition is water 14, silica 46.5 and alumina 39.5 per cent. However, such pure clay is never found in commercial quantities and the material actually used, contains small amounts of iron compounds, lime, magnesia, soda, potash and titania. Some clays also contain an excess of silica in the form of sand and some contain an excess of alumina due to the presence of some highly aluminous minerals. An analysis of a high grade Kentucky fire clay is as follows:

	Per cent
Silica, (SiO_2)	46.20
Alumina, (Al_2O_3)	37.02
Iron Oxide (Fe_2O_3)	1.72
Lime, (CaO)	0.44
Magnesia, (MgO)	Trace
Alkalies, (Na_2O) (K_2O)	0.50
Titania, (TiO_2)	1.50
Water, (H_2O)	13.42
	100.80

This type of clay is only slightly plastic and fuses at about 3250 degrees Fahr.

The closer the analysis of fire clay approaches the chemical composition of kaolinite, the more refractory it will be. This will be better understood when it is realized that impurities in fire clays exert powerful influences* Silica acts as a flux to high grade clays when heated above 2800 degrees Fahr. and it causes the brick to become friable. It also decreases the resistance of a brick, to spalling. Iron compounds act as powerful fluxes and

*Bales, C. E., *Brick and Clay Record*, Nov. 15, 1921.

as coloring agents. Iron in the ferrous condition is extremely harmful as it unites with silica to form ferrous silicate, a very corrosive and easily fusible slag. Lime and magnesia are both active fluxing agents and should not be present in high grade fire clays to the extent of over one per cent. Soda and potash act as fluxes but the best Kentucky clays contain less than one per cent of these substances. Titania decreases the refractoriness of fire clays, but it is not so active as the other fluxing impurities.

Properties of Air Furnace Brick

In discussing the properties of air furnace refractories, it

FIG. 5—A MACHINE FOR "DRY-PRESSING" FIRE BRICK

seems best to consider each type of brick separately. It is imperative that brick designed for use in bungs and roofs should be made from the highest grade clay obtainable and in no case should the finished brick contain less than 38 per cent of alumina. Bung brick are required to withstand high temperatures, to resist sudden changes of temperature and a little slag corrosion from the small amout of coal ash blown against them. A highly aluminous, coarse grained, open textured, soft burned brick gives the best service in bungs of malleable iron furnaces and in the roofs of air furnaces used in gray-iron foundries.

The following analyses are of bung brick that have given exceptionally good service in malleable iron furnace bungs and in the roofs of air furnaces:

Chemical Composition of Bung Brick

		Per Cent	Per Cent
Silica,	(SiO_2)	51.48	53.54
Alumina,	(Al_2O_3)	41.64	43.62
Iron Oxide,	(Fe_2O_3)	2.36	1.80
Lime,	(CaO)	0.20	0.30
Magnesia,	(MgO)	0.29	0.22
Alkalies,	(Na_2O) (K_2O)	0.86	0.94
Titania,	(TiO_2)	2.76	Undetermined.
		99.59	100.42

This type of brick was coarse grained, medium burned and its texture was open. It fused at 3254 degrees Fahr. When subjected to the standard load test of 25 pounds per square inch, at 2462 degrees Fahr. it was compressed 8.7 per cent. When heated to 2552 degrees Fahr. for five hours, it expanded only 0.11 per cent.

In examining bung brick one of the most important tests is the spalling test. This is conducted by heating one end of the brick in the door of a furnace operating at about 2400 degrees Fahr. for one hour. This brick is then partially immersed in water for three minutes and then replaced in the furnace. This procedure is continued until pieces of the brick fall off. Finally the specimen is weighed and the amount of spalling is reported as the percentage loss in weight. When the bricks having the

Table I

TESTS ON FIRE BRICK FOR MALLEABLE FURNACE BUNGS*

No.	Heats	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O Na_2O	Bulk spec. gravity	Per cent Porosity	Per cent deform. with load of 25 pounds per sq. in. at 1350°C	Fusion Cone	Method of making
1.....	18	52.93	42.69	1.98	0.33	0.38	1.55	2.04	15.50	12.2	32	Soft mud
2.....	18	52.20	43.42	2.18	0.40	0.40	1.47	2.00	15.60	15.2	30	Soft mud
3.....	18	Analysis undetermined						1.98	15.60	6.6	32½	Soft mud
4.....	14	52.60	43.22	2.00	0.40	0.30	1.68	1.89	19.40	4.6	32	Soft mud
5.....	12	52.60	43.71	1.98	0.41	0.30	1.68	1.94	15.90	12.8	32	Soft mud
6.....	3	66.22	29.83	1.12	0.27	0.29	1.24	2.03	13.40	11.8	30½	Dry press

*H. G. Schurecht, *Journal*, American Ceramic Society, Vol. III (7) July, 1920.

Table II

CHEMICAL COMPOSITION OF SIDE WALL BRICK

	Per cent
Silica (SiO_2).....	52.98
Alumina (Al_2O_3).....	41.06
Iron oxide (Fe_2O_3).....	1.83
Lime (CaO).....	0.27
Magnesia (MgO).....	0.13
Alkalies (Na_2O).....	....
(K_2O).....	0.81
Titania (TiO_2).....	3.15
	100.23

Table III

CHEMICAL COMPOSITION OF FIRE SANDS

	Lake sand Michigan	Crushed sandstone Ohio	Crushed sandstone Kentucky*	Sea sand Locality unknown**
Silica	99.02	96.80	98.84	89.99
Alumina	0.32	1.08		7.36
Iron oxide.....	0.12	0.70	0.50	0.85
Lime	0.20	0.26	0.20	0.46
Magnesia	Trace	0.12	None	Trace
Titania	....	....	0.19	....
Alkalies	0.16	0.28	....	1.17
Water	0.16	0.76	0.27	0.60

*C. H. Richardson, Kentucky Geological Survey, Series 6, Vol. I, 1920.

**F. W. Clark, United States Geological Survey, *Bulletin*, 695.

above chemical composition were subjected to this severe spalling test they lost less than 5 per cent by weight, after 20 immersions.

In actual service, bung brick spall either from sudden changes in temperature or from excessive stresses. The composition of the brick may be at fault in the first case, but the latter is brought about by improper installation, for example, applying too much pressure when the brick are being placed in the bung frames.

This type of bung brick when used in the hottest part of a malleable furnace usually lasts somewhat over two weeks, but in actual service, they are repaired every two weeks to prevent any of them from falling in during the melting period. In the cooler parts of the furnace these brick average 30 heats and in many cases have given 50 heats. In the roofs of gray iron air furnaces this same type of brick will average 18 heats.

The United States Bureau of Mines has done some work on bung brick and the data shown in Table I were obtained. These tests were conducted under actual service conditions and it seems that highly aluminous brick with high bulk specific gravity and low porosity are desirable for malleable furnace bungs.

The writer has had some experience with siliceous bung brick and it was found that brick containing over 62 per cent silica in the form of sandstone would only give about four heats in the roof of an air furnace.

Side Wall Brick

Bricks to be used in the side walls of air furnaces are made from the highest grade semiplastic clay mixed with a small amount of plastic material and are made by the "semidry-pressed" process.

This type of brick is not required to resist sudden changes of temperature but there is some cooling effect and the brick must be able to resist some spalling. It must withstand high temperatures and must resist corrosive slags and molten metal. An analysis of a "semidry-pressed" brick that has given ex-

cellent service in the side walls of air furnaces is shown in Table II.

This brick was fine grained, hard burned, and it had a close texture. It fused at 3230 degrees Fahr. When subjected to the standard load test of 25 pounds per square inch at 2462 degrees Fahr. it was compressed 5.1 per cent. When heated to 2552 degrees Fahr. for five hours, it expanded only 0.12 per cent. When subjected to the standard spalling test, it lost only 35 per cent by weight after 12 immersions.

In actual service these brick will average 20 heats in the hottest zone of the furnace and in the cooler parts, will give about 33 heats. This same type of brick is used in the bridge wall and in the angle walls.

Miscellaneous Shapes

In some cases a skew brick is used in each end of the bung, resting upon the side walls. These brick are made by the same formula and have the same properties as bung brick.

Tapping hole blocks and skimming hole blocks are made by hand from finely ground, highly refractory clays. They are burned hard. Wind bungs and tie brick, have the same composition and properties as bung brick.

Stack Brick

Brick to be used in air-furnace stacks must be very refractory and resistant to spalling. They have practically the same composition as bung brick, but they are ground finer and are burned to a slightly higher temperature.

Fire Sand

Fire sand commonly called "silica sand" is essentially silicon dioxide and is found in nature as quartz or rock crystal. Due to weathering and erosion, the mineral is broken up into small particles and the action of water gives the individual grains a smooth round surface. These grains are deposited in beds by rivers, lakes and oceans, but during the period of deposition, particles of many other minerals, such as muscovite, biotite, apatite, fluorite, calcite, hematite, feldspar, etc., are intermixed

with the quartz grains and the fusion point of the resulting sand is considerably lower than that of pure quartz. However, for foundry use, pure quartz sand is not required, as a small amount of impurities is necessary to sinter or fuse the sand grains together.

The sand actually used for lining ladles and building air furnace bottoms is lake sand, crushed sandstone and even ocean sand, although the latter contains much more fluxing material than the former. Typical analyses of sands used in air furnaces are shown in Table III.

The fusion point of commercial fire sand is about 3000 degrees Fahr. but when used in air furnace bottoms it is probably completely sintered together at a temperature of 2000 degrees Fahr. on account of the fluxing action of the iron oxide derived from the pig iron charge. A completely sintered bottom is necessary to obtain the most efficient service from an air furnace.

Some foundries use crushed fire brick for making air furnace bottoms and it gives perfect satisfaction, but in these furnaces, fire sand is used near the bridge wall. It seems that crushed fire brick would be the logical material to use, as a great many bung bats are available every time a furnace is repaired. The bats may be easily crushed by charging them with a few large pieces of pig iron into a revolving steel barrel, the staves of which are about 1/8 inch apart.

Raw Clays

A great deal of raw clay is used in the foundry in lining ladles, laying up fire brick and for daubing material. In laying up fire brick, only a thin batter of clay is used, but it must be refractory and of practically the same composition as the brick. A great many fire brick failures have been caused by using inferior clay and so called "special refractory cements," and the only safe method is to use finely ground fire clay with a small amount of ground fire brick. Some foundries use about 40 per cent of fire sand in mortar for laying fire brick, and it probably works all right so long as the sand is pure, but the chances of securing inferior sand are so great that it seems wise to eliminate

it from mortar, especially when it is known that silica acts as a flux to fire clay above 2800 degrees Fahr. and that bung brick frequently reach 3100 degrees Fahr.

For lining ladles a mixture of plastic refractory clay with a little fire sand, or ground fire brick, seems to give the best service. Excellent material for daubing up tapping holes and bungs can be made from 60 per cent ground fire brick and 40 per cent good plastic fire clay. Sizes of bung brick most commonly used are as follows:

Straight	*Arched*
inches	inches
9x4½x2½	9x4½x2½—2⅜
13x4½x2½	13x4½x2½—2⅜
12x6x2½	
13x6x2½	
13½x6x2½	

Some malleable iron foundries are now using the following size bung brick.

Straight	*Arched*
inches	inches
9x4½x3	
13x4½x3	13x4½x3—2⅝
13x6x3	13x4½x3—2⅞
13½x6x3	

These thicker brick give perfect satisfaction and every fire brick manufacturer interested in seeing the foundryman obtain maximum service from his bung brick will recommend them, because the 3-inch have a great many advantages over the 2½-inch brick, without a single disadvantage.

In the manufacture of 3-inch brick they can be made straighter and truer to size than the 2½-inch brick, and as they are much stronger, fewer brick will be broken during the time of transportation and unloading. In building the bungs, some time can be saved as fewer brick will be required. The number of joints between the brick will be reduced and less fire clay mortar will be used.

The writer desires to acknowledge his indebtedness to the Louisville Fire Brick Works for permitting the publication of the data presented in this paper.

Behavior of Fire Brick in Malleable Iron Furnace Bungs

By H. G. SCHURECHT, Columbus, O.

In the utilization of fire clays for malleable iron furnace bungs, manufacturers have experienced trouble in producing brick of high service due to lack of knowledge of the constitution and properties such brick should possess. Brick made of clays passing the customary load and softening-point tests often fail when used in malleable iron furnace bungs. For example, in one case a brick standing a high load test failed under three heats in practice, whereas, another brick failing in the load test stood an average service test of 17.5 heats.

In selecting clays for bung brick actual service tests consume too much time, whereas laboratory tests can be made quickly. Therefore a more thorough study of the relations existing between laboratory tests of bung brick and their ability to stand up in practice was undertaken by the ceramic station of the United States Bureau of Mines. Although the investigation was limited to brick used in malleable iron furnaces, the results may be applied to refractories for other furnaces requiring similar service.

Description of Tests in Practice

Complete seven-foot arches containing 40 brick were tested as shown in Fig. 1. The number of heats withstood by the different arches in practice was used as a method of comparing the serviceability of the different brick tested. All the bungs tested were placed in a definite position over the firebox where they received the same and the severest heat treatment of the furnace. After each heat, the bungs were removed from the furnace during the recharging. This chills the brick and tends to cause spalling. The tests were made in a 40-ton malleable iron furnace operated by the Ohio Malleable Iron Co., Columbus, O. Three or more bungs of each brand of brick were tested.

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Description of Laboratory Tests

The following factors were investigated in laboratory tests made on each brand of brick:

1. Per cent spalling loss.
2. Per cent deformation under load.
3. Density.
4. Per cent apparent porosity.
5. Softening temperature.
6. Chemical analyses.
7. Permeability of gases.

For the spalling test four or more brick of each brand were selected, those showing cracks and flaws being discarded. The brick were dried at 110 degrees Cent. for five hours or more, and weighed.

The test furnace was heated to 1350 degrees Cent., and held at this temperature for one hour. The bricks then were placed in pairs in 5 1/4 x 4 5/8-inch openings left in the doorway of the furnace, with the 2½ x 4½-inch ends exposed to the fire, and heated one hour before quenching.

Two bricks at a time were removed and plunged into running water (at about 20 degrees Cent.) to a depth of four inches and held three minutes, after which they were removed and allowed to dry three minutes in air. As soon as two bricks were removed from one of the openings they were replaced by two others, thus preventing cooling of the furnace.

Each brick was heated and quenched 10 times. After the tenth quenching the brick were dried at 110 degrees Cent., for five hours and all particles easily removable by the fingers were broken off. The brick were then weighed and the percentage loss in weight calculated on the basis of the original weight.

The resistance of fire brick under load was determined by applying a load of 25 pounds per square inch to the bricks and heating them to 1350 degrees Cent., and holding the furnace at this temperature for 1 1/2 hours. The per cent deformation was noted and used as a measure of the resistance to load at furnace temperatures; see *Journal,* American Ceramic society, Vol. II., pp. 602-7, (1921).

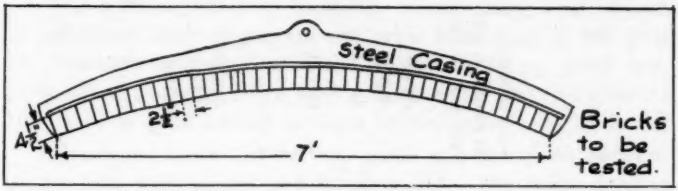

FIG. 1—MALLEABLE FURNACE BUNG AS TESTED

The softening temperatures were determined by comparison with standard Orton cones. The apparent densities and porosities were determined by the water and oil immersion methods and calculated as follows:

$$D = \frac{W_d}{V_b}$$

D=Density
W_d=dry weight
V_b=bulk volume (true clay volume plus pores)

$$P_a = \frac{W_s - W_d}{V_b} \times 100$$

P_a=per cent apparent porosity.
W_s=saturated weight (saturated in water).

The permeability of gases through the brick was measured by forcing air at a low pressure through the 2 1/2-inch thickness of the brick.

Results of Tests in Practice and in the Laboratory

The results of this investigation are shown in part in Tables I and II and Figs. 2, 3, 4, 5, 6, and 7. The results indicate that the load test is no criterion of serviceability in malleable iron furnace bungs. For example, bricks *A* and *B* behaved poorly in the load test but stood up well under service, while bricks *I* and *M* stood up well in the load test but behaved poorly in service. Obviously the brick should be strong enough to support the arch at high temperatures, but any extra strength above a safe limit is unnecessary. Brick deforming as much as 6.35 per cent under the load test in some instances gave excellent service in the malleable iron furnace bungs.

Table I

THE PROPERTIES OF MALLEABLE IRON FURNACE BUNG BRICK

	No. heats bungs in	Per cent spalling loss	Per cent deform. under load	Softening point of brick cones	Softening point of bond clay cones.	Density	Per cent apparent porosity	Permeability of gases, cc. per sec. per sq. cm.
L	19	1.30	0.90	..	..	2.282	20.87	0.0407
B	18	6.94	4.85	30-32	30-31	2.044	22.04	0.2070
C	18	7.92	1.95	32	32	2.025	23.15	.....
A	17.5	2.56	6.35			1.985	24.78	.....
H	17	5.18	0.40	32	30	2.043	19.03	0.1733
D	16.7	2.99	2.05	32	31	2.113	21.67	.....
K	16.5	5.80	....	..	..	1.958	25.51	.....
G	15.0	4.36	6.90	32	30	2.188	16.80	.....
E	15.0	5.31	7.00	27	26	1.976	25.34	0.0630
I	10.0	20.36	1.10	32	30	2.123	15.11	0.1828
M	9.5	28.20	0.65	..	..	1.910	24.92	0.1988
J	8.0	11.94	....	..	..	1.888	27.86	.....
F	3.0	12.51	2.80	..	..	1.910	20.56	0.1959
Carborundum	24+	½	....	..	..	.....	.....	.....

The softening-point of malleable furnace bung brick should be sufficiently high to prevent the brick from melting but it is not necessary for them to stand a high softening point test, (cone 31 or above). Brick having a softening point of cone 30 often give as good service as those softening at cones 31 to 33.

The closest relation of the tests made appears to be between the per cent spalling loss and serviceability. The brick showing the smallest spalling loss stand up best in practice (see Fig. 2).

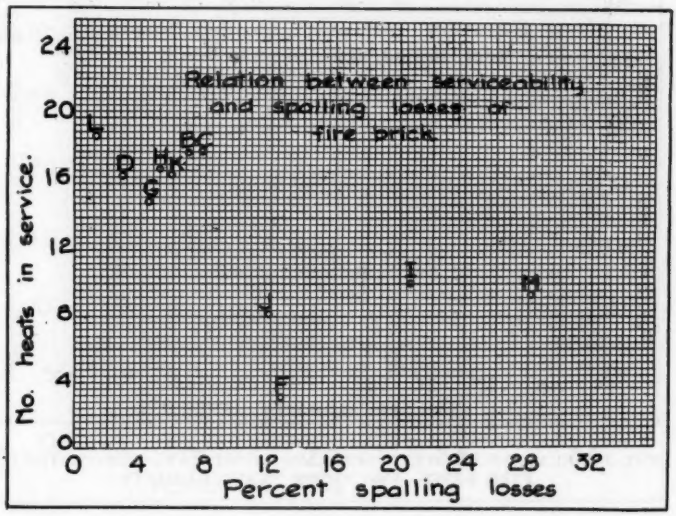

FIG. 2—RELATION BETWEEN SERVICEABILITY AND SPALLING LOSSES OF FIRE BRICK

When the spalling loss was above 8 per cent the number of heats which the corresponding bricks withstood in practice was below 15 in each case.

There appears to be a relation between the porosities of fire brick and their resistance to spalling and their serviceability, (as indicated in Fig. 3). If a brick is too dense it cracks, due to differences in expansion of different portions of the brick. A more porous brick is less brittle and yields without cracking to these differences in expansion. When a brick is too

porous, however, it also spalls readily. This may be due to the fact that porous bricks lack mechanical strength and have a higher coefficient of expansion as compared with the more vitreous bricks, which was shown in Ricke's work, *Keram. Rundschau.* Vol. XIV, pp. 143-145, (1914).

Corrosive gases and slags also penetrate a porous brick more readily than a denser one, which would result in producing

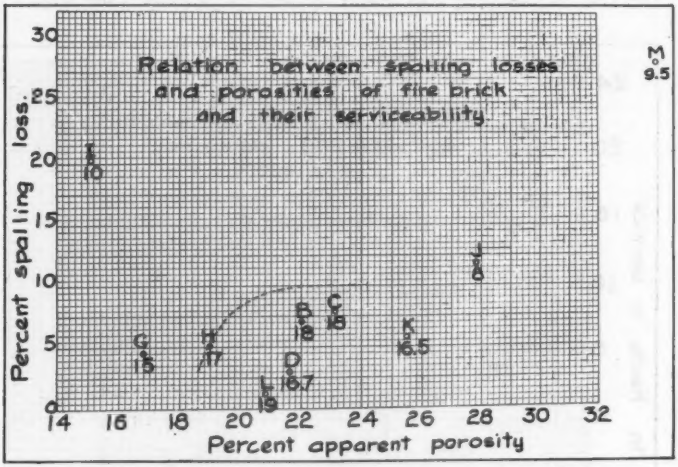

FIG. 3—RELATION BETWEEN SPALLING LOSSES AND POROSITIES OF FIRE BRICK AND THEIR SERVICEABILITY

a more brittle brick and hence one which is more susceptible to spalling.

In examining the density and porosity data in Table I and Figs. 3 and 6, it appears that the dense, nonporous bricks give better service than the more porous ones, provided the porosity is not too low, in which case the spalling tendency is increased.

The brick giving best service had porosities between 15 and 28 per cent, and densities between 1.9 and 2.3. The brick whose porosities and densities were outside of this field gave comparatively poor service.

In examining the chemical analyses in Table II and Fig. 4

it is evident that the ratio of RO_2 to $RO+R_2O_3$ of the best brick lies between 1.5 and 2.6. If the RO_2 (i. e. SiO_2) content is too high, too much free or uncombined silica is present, which increases spalling during heating and cooling, due to the volume changes during the transition of SiO_2 into its various forms at different temperatures. SiO_2 is also more vigorously attacked by the basic slags and gases than Al_2O_3.

Spalling tests were made on a number of different refrac-

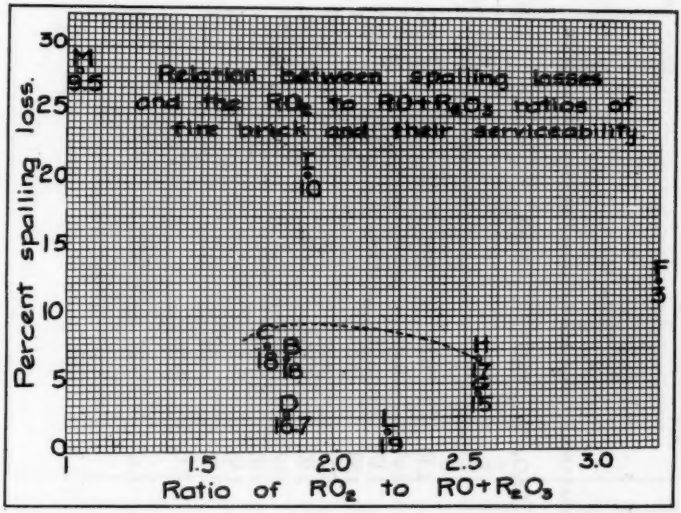

FIG. 4—RELATION BETWEEN SPALLING LOSSES AND THE RO_2 TO RO + R_2O_3 RATIOS OF FIRE BRICK AND THEIR SERVICEABILITY

tories to determine whether some other refractory was more resistant to spalling than fire clay brick. The results are given below:

Type of refractory	*Per cent spalling loss*
Firclay brick	0.63-49.5
Carborundum brick	0
Magnesite brick	Lost over 90 per cent after second quenching
Silica brick	Lost over 50 per cent after second quenching

It is obvious that carborundum brick are much more re-

Table II

CHEMICAL ANALYSES OF MALLEABLE IRON FURNACE BUNG BRICK

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Alkalies	$\frac{RO_2}{R_2O_3}$	$\frac{RO_2}{RO+R_2O_3}$	No. heats in malleable furnace bungs.
L	54.73	39.25	2.10	0.05	0.05	1.10	2.30	2.21	19
B	52.20	43.42	2.18	0.40	0.40	1.47	1.98	1.83	18
C	51.04	41.04	2.17	0.65	0.00	4.48	2.05	1.75	18
A	52.93	42.69	1.98	0.33	0.38	1.55	2.04	1.89	17.5
H	58.36	28.76	8.20	0.00	0.30	3.02	2.93	2.57	17
D	52.60	43.22	2.00	0.40	0.30	1.69	2.01	1.84	16.7
K	54.65	41.36	2.02	0.48	0.29	1.12	2.18	2.03	16.5
G	58.36	28.76	8.20	0.00	0.30	3.02	2.93	2.57	15.0
E	52.16	43.71	1.98	0.41	0.30	1.68	1.96	1.82	15.0
I	53.75	41.50	2.08	0.39	1.75	....	2.14	1.91	10.0
M	38.40	56.75	2.95	trace	1.10	0.85	1.11	1.04	9.5
J	.....	.....	....	....	....	....	.. .	....	8.0
F	66.22	29.83	1.12	0.27	0.29	1.24	3.69	3.24	3.0
Carborundum	.....	.....	....	....	....	....	....	....	24+

sistant to spalling than the other refractories tested. Several bungs of carborundum brick were therefore tested in malleable iron furnace bungs.

One of the bungs stood up well after 24 heats after which it was removed because of its high heat conductivity. This service is much higher than that of the fire clay brick tested.

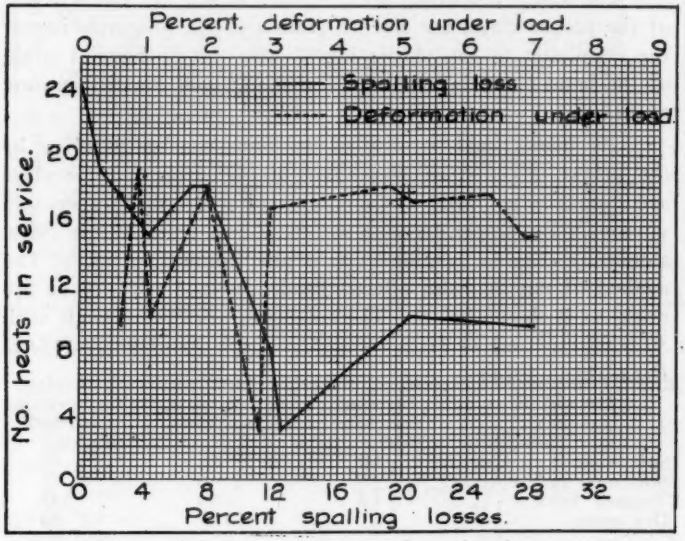

FIG. 5—SPALLING LOSSES COMPARED WITH DEFORMATION UNDER LOAD

The second bung, however, broke the steel casing due largely to the greater weight of the carborundum bricks as compared with fire clay brick. The high heat conductivity of carborundum brick caused the outer surface of the brick to become red, thus allowing considerable heat loss.

By designing special bung casings much stronger than those used, and by using an insulator between the iron casing and the brick to prevent heat losses, carborundum brick may prove to be an excellent refractory for malleable iron furnace bungs because of their great resistance to spalling, and longer services.

However, carborundum brick are much more expensive than fire clay brick.

It was found that a nonspalling brick gave the best service. A dense nonporous brick gave better results that a more porous brick, provided it was not so dense as to be brittle and thus increase the spalling tendency.

The above properties are governed largely by the selection of the proper clays, the size of grain and the proportioning of the nonplastic to the plastic ingredients, the fineness of grain of the bond clay, the manner of molding, and the temperature of firing.

The density and porosity of fire brick can be controlled by the proper selection of clays, and proper firing. Some clays are porous when fired at high temperatures, while others are vitreous. By proper blending of these two types of fire clays, a mixture may be obtained giving any desired porosity. The method of molding also affects the density and porosity of fire brick, as is shown below. The following brick were made with 30 bond clay and 70 grog, *Verlin deutschen Fabriken feuerfeste Produckte,* (1914).

Method of molding.	Per cent shrinkage	Per cent absorption	Compression strength Kg/cm2
Soft mud	5.0	10.7	87
Soft mud and repress.	4.9	9.6	88
Tamped brick	4.8	8.9	103
Dry press.	5.1	12.7	50

These results show that a mixture with less water than soft mud consistency and with more water than dry press consistency produces the densest brick, providing sufficient pressure is used in molding.

The size of grain and proportioning of flint clay has a marked effect on the spalling tendency. Brick containing a high percentage of coarse grog are more resistant to spalling than those containing fine grained grog. A series of tests in which 1 x 1 x 8-inch bars were heated to 600 degrees Cent. and quenched in water until they broke were conducted by Kirkpatrich on bars containing 50 per cent bond clay and 50 per cent grog. The average results obtained with the different series are given below and show that using coarse grog instead of fine increases the

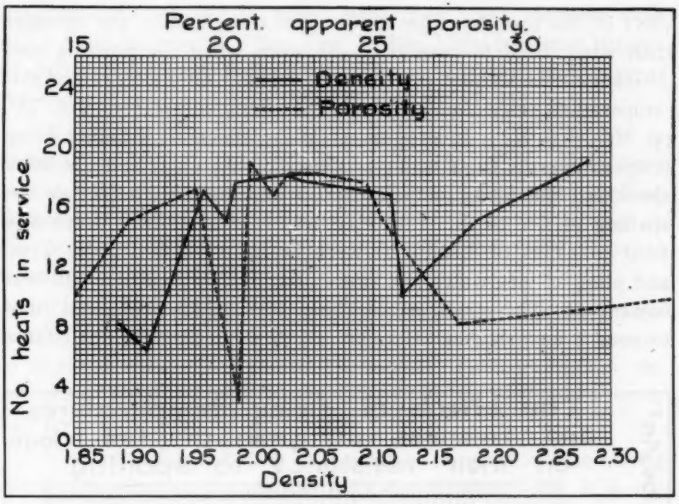

FIG. 6—DENSITY OF FIRE BRICK COMPARED WITH POROSITY

resistance of fire brick to spalling, *Journal,* American Ceramic society, Vol. XIX, p. 287, (1917).

Size of grog in mixture	Number of quenchings. before specimens broke due to spalling.
4-20 mesh	11.1
8-20 mesh	9.3
12-80 mesh	7.5
20 dust	4.7

Increasing the percentage of flint clay and reducing the percentage of bond clay increases the resistance of fire brick to spalling within certain limits as was shown by Howe, *Journal* American Ceramic society, Vol. IV, p. 119, (1921).

The size of grain of the bond clay also affects the spalling tendency of fire brick. For example, it is shown in Fig. 7 that fire clay screened through a 20-mesh sieve is much more resistant to spalling than the same clay ground fine enough to pass a 150-mesh sieve.

Different firing temperatures have a marked effect on the properties of fire brick. For example, it was found that when

clays of the fire clay type are fired to cone 8, they are stronger than when fired to cone 6 or 10, even when the porosity and shrinkage data showed the bodies to be over or underfired at this temperature. See *Journal* American Ceramic society, Vol. IV, pp. 366-74 (1921). Investigations on the effects of different firing temperatures on the spalling tendency of fire clays and fire brick show that the firing temperature has an important effect on the spalling of fire brick. Fire clay bars 1 x 1 x 8-inch previously fired to cones 6, 8, and 10 were heated to 600 degrees Cent. and plunged into water five times after which their strength was measured. The strengths of those bars which had been fired to cone 8 were higher after the quenching treatments than those

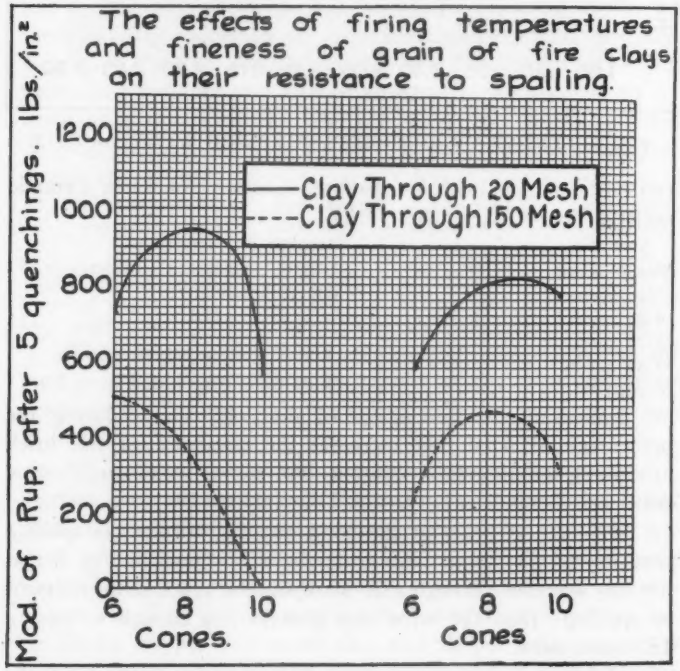

FIG. 7—THE EFFECTS OF FIRING TEMPERATURES AND FINENESS OF GRAIN OF FIRE CLAYS AND THEIR RESISTANCE TO SPALLING

fired to cone 10 and in some cases they were stronger than those fired to cone 6. See Fig. 7. See United States Bureau of Mines Technical Paper 233, 26 pp., (1920) and *Journal* American Ceramic society, Vol. IV, p. 40, (1921).

It appears, therefore, that by firing to cone 8 a product is obtained which is more resistant to spalling than when fired to cone 10, and in some cases they are more resistant to spalling than those fired to a lower temperature. This may be due to the presence of sillimanite and free silica in the fire brick, which are formed at high temperatures.

The work on malleable iron furnace bung brick which has been done up to the present time has not been extensive enough to draw definite conclusions. The writer, however, offers the following summary which applies only in so far as the work has progressed:

Fire brick for malleable iron furnace bungs should be strong enough to support the arch at high temperatures, but it is not necessary that the bricks should stand as high a load test and fusion test as are required for No. 1 fire brick. Fire brick which may deform as much as 6.35 per cent in the load test may be serviceable as bung brick in malleable iron furnaces.

Although brick which pass high load and softening point tests often give good service in practice, many which pass these tests fail.

The spalling test bears the closest relation to the service test. When the spalling loss was above 8 per cent, the number of heats which the corresponding brick withstood in practice was below 15. In general, brick showing a spalling loss below 8 per cent stood 15 or more heats in practice.

The brick giving best service had porosities between 15 and 28 per cent and densities between 1.9 and 2.3.

The RO_2 to $RO+R_2O_3$ ratios of the best brick were between 1.5 and 2.6.

Carborundum brick withstood more heats than any fire clay brick tested, but are objectionable due to their high heat conductivity and greater weight. These objections, however, can be overcome by using heat insulation and stronger casings.

In the manufacture of malleable iron furnace bung brick,

their properties may be governed by the selection of the proper clays, the size of grain and the proportioning of the nonplastic and plastic ingredients, the fineness of grain of the bond clay, the manner of molding, and the temperature of firing.

In conclusion, the author wishes to acknowledge his indebtedness to J. M. Kittle of the Ohio Malleable Iron Co., and H. S. McDowell of the Harbison-Walker Co., for their cooperation in this work.

Discussion—Behavior of Fire Brick in Malleable Iron Furnace Bungs

By C. E. BALES, Louisville, Ky.

This paper is a valuable contribution not only to the user of refractories, but also to the manufacturer. We fully agree that the load test is of no value in determining the quality of bung brick as we know of brick deforming as much as 8.7 per cent in this test, which gave excellent service.

In our work the brick showing the least spalling loss has always given the best results in actual service. We have found that brick with a high fusion point (Cone 33), iron oxide content less than 2.5 per cent and alumina between 40 and 45 per cent have stood up best in service. Brick high in silica (68 per cent) gave only four heats in service, the failure being due to spalling.

Our experience agrees with Mr. Schurecht's opinion that the porosity of fire brick is an important property and that bung brick will fail if they are too porous as well as if they are too dense.

We were surprised to learn that bung brick with 8.20 per cent Fe_2O_3 would give 17 heats in a malleable iron furnace.

It is doubtful if carborundum brick will ever be used extensively in malleable iron furnaces on account of their high cost, high heat conductivity, their weight, and the fact that they begin to dissociate at about 2725 degrees Fahr. under oxidizing conditions and at about 3100 degrees Fahr. under reducing conditions.

Relation of Temperature to Form and Character of Graphite Particles in the Graphitization of White Cast Iron

By Edward J. P. Fisher, Worcester, Mass.

During the summer of 1920, the author became interested in the theory and practice of malleable iron manufacture, having worked in the Toledo plant of the National Malleable Castings Co. Upon returning to school the following fall, he took up casual studies of the theories involved. When required to present a thesis subject, he obtained the above, through the kind advice of H. A. Schwartz, manager of research, of the afore-mentioned concern.

The thesis, from which this paper has been prepared, was submitted to the faculty of the Worcester Polytechnic Institute. Worcester, Mass., June, 1921, for the degree of Bachelor of Science in Chemistry. The author wishes to express his appreciation of the assistance and encouragement given him by Prof. R. C. Sweetser, under whose guidance the work was brought to completion. He also acknowledges his indebtedness to Prof. D. F. Calhane and to Carlton D. Haigis for their many helpful suggestions on the thermoelectric work connected with the thesis.

The author has endeavored to obtain and compile a series of original microphotographs, for the purpose of showing, visibly and analytically, the relation of temperature to the form of carbon particles, which depends upon the physical properties of the medium in which those particles find themselves precipitated. Also he attempted to show the relation of the character of the particles to the physical properties of the white iron annealed.

The most recent works on the theory of graphitization in cast iron, have been summed up in a book by Hatfield[1]. Paul D. Merica, in a Bureau of Standards *Bulletin*,[2] gives a digest

[1]W. H. Hatfield—"Cast Iron in the Light of Recent Research" J. B. Lippincott Co. 1918.

[2]Paul D. Merica. Bureau of Standards Technologic Paper No. 129. "Notes on the Graphitization of White Cast Iron upon Annealing."

of the conclusions reached by investigators as most plausible to date, and which reads as follows:

1. Whether a given mass of molten iron becomes white, mottled or gray upon casting, depends upon its composition and its rate of cooling through the temperature range of solidification, and immediately below:

2. The more rapid the rate of cooling the less is the extent of graphitization.

3. *Graphitization* increases with increase of carbon or silicon content; it decreases with increasing sulphur content. Manganese plays a double role, by combining with sulphur, it first neutralizes the specific effect of the sulphur; an excess of manganese restrains graphitization.

4. Upon annealing irons which have solidified *white*, the combined carbon decomposes into graphite or temper carbon, at temperatures between 700 and 1100 degrees Cent., depending upon the period of annealing, and the composition of the metal. Those elements which promote graphitization upon casting and solidification, promote it also during annealing by lowering the temperature range, within which, decomposition of cementite, Fe_3C, is possible.

5. After nuclei of graphite have once formed, further graphitization proceeds more rapidly, and, at lower temperatures than in iron of the same composition in which no nuclei are present.

The work of this thesis has been directed mainly to the verification of the time and temperature theory as given under paragraph 4, preceding. Any variations in effects, due to chemical composition, were eliminated by using a set of test samples, all poured from the same composition melt or heat. The temperature factor has been varied, and the time factor kept constant, so that proof could be shown for the following, more detailed theory:

First.—That, with a series of white irons of constant chemical compositions, the rate of precipitation of temper carbon, by annealing in a non-oxidizing bath, increases proportionally with the temperature of annealing, and that this can be shown through the microscope, by the relative sizes and concentrations of the particles of temper carbon.

Second.—That, with the same iron, the increases in the rate of graphitization with the rise in temperature of anneal, is due to the relative mobility of the medium in which the carbon finds itself precipitated. Therefore a series of microstructural cuts will show an increase in flakiness of the graphite particles as the temperatures of the anneals are raised.

Third.—That, as the temperatures of the anneals are increased gradually toward the melting point of the iron, there is a "critical" temperature, just below that point, at which the carbon is no longer precipitated as temper carbon, but as ordinary flaky graphite crystals

found in gray iron. The exact "critical" point could not be shown by the photomicrographs, because of the lack of time for obtaining specimens annealed at the higher temperatures. Incidentally the author has produced several cuts which show the verity of the theory given under paragraph 5 preceding, concerning the effect of preformation of graphitic nuclei.

The general and specific theories on the whole subject of malleable cast iron have been treated by such men as Moldenke[3], Chadsey[4], Sauveur[5], H. A. Schwartz[6].

Description of Apparatus

One of the most important pieces of apparatus, needed for the experimental work was a furnace, or sufficiently accurate and extensive temperature control, for annealing samples of white cast iron. For laboratory practice, the most reliable type of furnace is the electric, wire wound, resistance furnace. Since all furnaces of this description at the institute were in use, one had to be constructed.

The external features of the electric furnace are described as follows:

Through the kindness of Ralph M. Johnson of the sales department of the Norton Co., Worcester, an alundum tube was presented to the department of chemistry for the work. The tube was 15 inches long and of 2 inches inside diameter, with walls 3/16 inch thick. A coil of nickel-chromium wire, No. 20, was wound around the tube, 250 feet of wire being used. The coil was wound in spiral formation and was kept in place and insulated by a mixture of alundum cement and water, applied first as a paste, dried in air, then in an oven and finally by the heat of current through the coil. This gave a compact resistor core which was ready for external appliances.

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[3]Moldenke—"Judging Fractures of Malleable Iron." *Foundry* Vol. 37, p. 237.

[4]Chadsey—"Experiments on Annealing Malleable Cast Iron." *Foundry*, Vol. 37, p. 215.

[5]A. Sauveur—"Metallography of Iron and Steel." Second Edition. Publishers, Sauveur and Boylston.

[6]H. A. Schwartz—"Properties of Malleable Iron."—*Engineering News-Record*. Vol. 83, p. 132, and "Effect of Manganese on Malleable Iron." *Chemical and Metallurgical Engineering*. Vol. 24, No 21, p. 912.

The resistance of the embryo furnace then was tested by means of the fall in potential across a Wheatstone bridge and galvanometer in circuit. The resistance was found to be 216 ohms, and since this was too high, the coil was divided into five equi-resistant parts of 43.2 ohms each, which were connected in parallel.

Over each end of the alundum core, there was fitted a circular piece of asbestos board. That is, a hole 2¾ inches in diameter was cut out in the center of each circular asbestos plate, by jig-saw. The plates themselves were 10 inches in diameter and about ¼ inch in thickness. These two end plates were held in place by four ⅛-inch iron rods, which were threaded at one end for a nut, and capped at the other. The outer face of each plate fitted flush with the corresponding end of the alundum core. In order to cover the two openings, two discs of asbestos board were cut out, about 4 inches in diameter, and held in a swinging position by a screw pivot A hole was bored in one of the swinging discs, to allow for the insertion of a ½-inch alundum pyrometer tube. About the core and resistor were placed two semi-cylindrical pieces of magnesia-asbestos pipe casing, about 1½ inches thick, for insulating the heated center. With this insulation, the cooling rate of the furnace was reduced to a desirable degree.

To regulate the intensity of the heating current, an external resistance, with sliding contact, was connected in series with the furnace. In this way the current could be decreased from maximum of 11.3 amperes to a minimum of about 4 amperes, giving a temperature range of 1000 degrees Cent. down to about 500 degrees Cent. In practice the furnace was used on a 110 alternating current line, connected in series with an ammeter, and the rheostat. As no voltage regulator was at hand the accuracy of temperature determinations fluctuated within plus and minus 15 degrees Cent.

Temperature Control

A platinum and platinum-iridium thermocouple served as a means of determining temperatures of the interior of the fur-

nace. The thermocouple was made of two strands of wire, one of platinum and the other of an alloy of platinum and iridium, each about 15 inches long and welded together at one end. The welded point was the hot junction of the couple. The strands were insulated from each other by using a porcelain tube. The open ends were connected to form a circuit through a calibrated high resistance and a sensitive galvanometer. A diagram of the complete set-up of the furnace and thermocouple arrangement is shown in Fig. 1.

Other Apparatus

Besides the heat-treating appliances, there was apparatus necessary for the microphotographic work involved. This apparatus consisted of a Bausch & Lomb type vertical microscope, with adjustments for fitting various lenses. There was also attached to the barrel of the microscope, a plain glass disc vertical illumina-

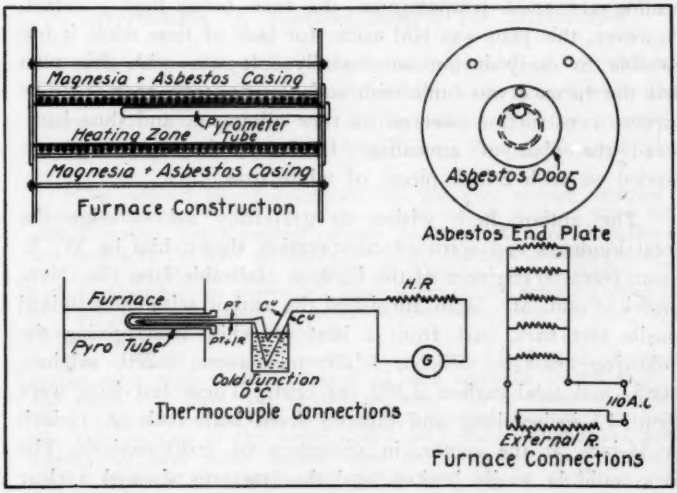


FIG. 1—DIAGRAM OF FURNACE AND CONNECTIONS

tor. The microscope was placed in position under a vertical telescopic camera, with plate-holder attachment at the top, and a light-tight fitting with the microscope at the bottom. Illumination was afforded by means of a beam of light from a 110-volt alternating current arc lamp.

Experimentation

Briefly, the experimentation consisted in the annealing of 14 pieces of white iron. After annealing, each of these test pieces at a different and selected temperature, each one was cut in half, and a cross section ground down and polished, to within the range of microscopic scratches. Each of these sections were then photographed through the microscope, and the plates developed and printed. A more detailed explanation of the work done is given as follows:

Annealing

It was the original plan of the author to anneal full length test bars, cast from white iron, and then make standard tension tests on these bars, for relative physical properties after annealing at varied temperatures, the time being kept constant. However, this plan was laid aside, for lack of time made it impossible to carry it out successfully. It was with this plan that the furnace was built with such lengthy proportions. The furnace construction overran its time allotment, and thus hampered the plan of annealing. However, the annealing was carried on with 2-inch pieces of white iron.

The author here wishes to gratefully acknowledge the great kindness and spirit of co-operation shown him by W. R. Bean, research engineer of the Eastern Malleable Iron Co., Naugatuck, Conn. Mr. Bean furnished the author with 20 standard tensile test bars, cast from a heat of white iron, giving the following analysis: Silicon, 1.120; manganese, 0.270, sulphur, 0.085; and total carbon 2.380 per cent. These test bars were about 13 inches long and tapered from both ends at ¾-inch to ⅝-inch at the center, in diameters of cross-sections. The bars could be easily broken, and the fractures showed a clear white crystalline structure, characteristic of hard white iron.

The first three pieces of white iron annealed, were placed in the furnace, surrounded by a packing of crushed hematite ore. The first two runs, Nos. 1 and 2, were only feelers, and could not be used for the regular set of plates, so have been omitted. The remaining 12 runs have been recorded on pages following. Runs Nos. 4 to 14 inclusive, were made with the test pieces packed in sea sand or non-oxidizing packing.

In starting an anneal, the furnace, containing the sample, packing and the thermocouple, was brought up to the heat desired, within two hours, from room temperature. The current was then regulated to give constancy to the temperature desired, which required at least an hour for proper regulation. After this, the furnace could be left running with little watching except when the current supply had to be shifted from the Institute power to the City power. Runs were continued for at least 30 hours. The thermocouple-galvanometer circuit was kept open, except when temperature readings were taken, avoiding changes in the readings due to temporary or permanent distortion of the wire holding the moving coil of the galvanometer.

*Preparation of Annealed Sample for Microscope**

After annealing, the sample was cleaned of its external, brittle silicide shell, and sawed in half with a hack-saw. Both pieces were then ground off at the sawed ends by a circular face-grinding wheel, in the Washburn Shops. One of these

*The original photomicrographs did not give enough contrast to allow for taking of cuts, therefore a new set of pictures were taken with a regular metallographic set-up. A Bausch & Lomb metalloscope was used with the kind permission of V. E. Hillman, metallurgist at the Worcester plant of the Crompton & Knowles Loom Works. The author wishes here to express his appreciation of the great aid given him by Earl D. Clark, metallographist at the same plant, in the actual photomicrographic work involved.

The original annealed specimens were repolished, and all photographs were made with the center of each specimen in the field. It was noted that there was usually an outer rim of decarburized iron. Thus, using the center as a field, the decarburized portions were avoided. One or two of the samples had very wide decarburized areas, which may have some bearing upon the irregularities, to be noted in the following few pages, but which were few in number.

The Nital etching solution used was a 10 per cent nitric acid-alcohol solution, used cold.

pieces was taken for fine polishing. The polishing was done in steps, as follows:

1. Coarse carborundum cloth. } Hand polishing on
2. Medium carborundum cloth. } plate glass covered
3. Fine emery cloth. } with the abrasive.
4. Fine emery powder on cloth wheel
5. Rouge on plush wheel.

In each step, the marks of the step preceding were eradicated by rubbing at 90 degrees with the marks of the preceding step. This was continued through the five steps until the last gave only a few scratches, visible under the microscope. More time was not at hand for greater fineness in polishing. Etching was omitted, because of the natural prominence in contrast, of the carbon particles. Many helpful suggestions for this work were found in Sauveur's "Metallography of Iron and Steel."

The microphotography work consisted in taking photographs of the polished iron through the microscope, with the set-up, described. The photographic plates used for this work were Eastman-type standard dry-plate, 4 x 5 inches. This is an extra fast plate, and probably too much so, for the brilliant illumination given by the arc lamp. However, the results obtained were satisfactory, after a few 'feeler' attempts. All photographic work was done in the evening, after dark, thus avoiding accidental exposures. The plates were developed by an outside concern, while printing was necessarily done at the laboratories, because of extra care needed with the varying contrasts in the negatives.

Tabulation of Data

Number	*Runs Tabulated According to Numbers* *Time of Anneal hours*	*Average of Degrees Cent.*	*Temperatures Degrees Fahr.*
3	87	825	1517
4	20	900	1652
5	51	995	1823
6	43	1075	1967
7	32	890	1634
8	30	955	1751
9	34	1000	1832
10	28	850	1562
11	31	970	1778
12	31	940	1724
13	31	1150	2102
14	32	1100	2012

The microscope, in every case, was fitted with a 16-millimeter objective lens, and an eye-piece of two inches focal length. The two ends of the bellows camera were kept at the same distance apart, in every case. These three specifications insured one definite degree of magnification for every specimen, observed and photographed.

This table is compiled from data of runs taken in sequence of their completion. Runs Nos. 3, 4, 5, and 6 are irregular, and will be discussed in a group by themselves. Runs Nos. 7 to 14, inclusive, are discussed in a second group, both individually and as a group. The runs of this group are tabulated below according to temperatures, and the discussions follow the same sequence.

Runs Tabulated According to Temperatures

Temperature		*Time of Anneal*	*Run Numbers*
Degrees Cent.	*Degrees Fahr.*	*hours*	
850	1562	28	10
890	1634	32	7
940	1724	31	12
955	1751	30	8
970	1778	31	11
1000	1832	34	9
1100	2012	32	14
1150	2102	31	13

The actual readings for each anneal are given on the page containing the microphotographic plate of each sample.

Photographs and Discussions of Individual Plates

On the following pages are found the microphotographs of the 12 samples annealed, each in their proper order according to temperature of anneal. With each micrograph there is a set of data upon the anneal.

The plates are divided into two groups: Group I contains the irregular anneals and Group II includes the anneals which have time constant and temperatures increasing in sequence.

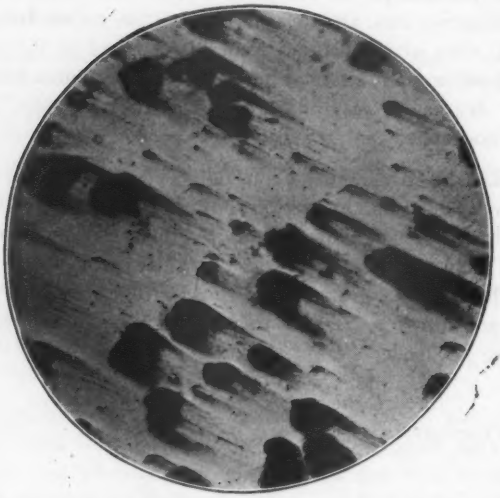


FIG. 2—RUN NO. 3; TEMPERATURE OF ANNEAL, 1517 DEGREES FAHR.; TIME, 87 HOURS; PACKED IN CRUSHED HEMATITE ORE — × 100

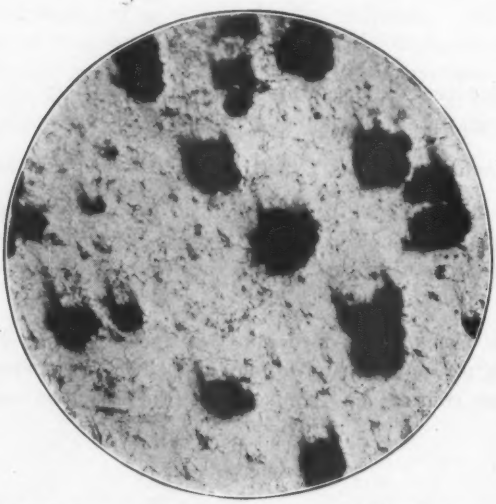


FIG. 3—RUN NO. 3. COMPLETELY MALLEABLIZED CAST IRON

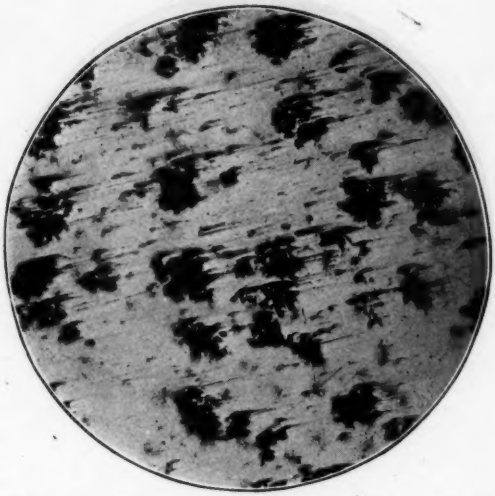


FIG. 4—RUN NO. 4; ANNEALED AT 1652 DEGREES FAHR., 20 HOURS; PACKED IN WHITE SEA SAND — × 100

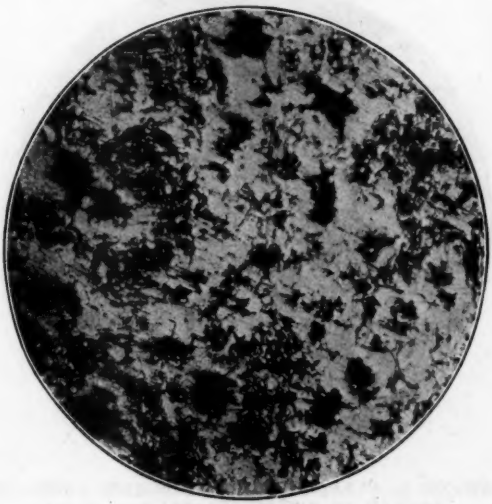


FIG. 5

FIG. 6—RUN NO. 5; ANNEALED AT 1823 DEGREES FAHR.; 54 HOURS; PACKED IN WHITE SEA SAND

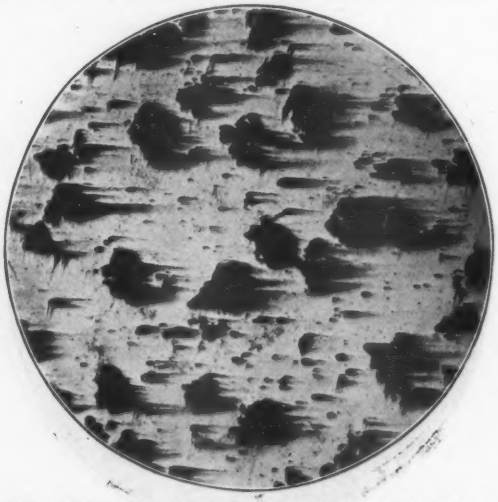


FIG. 7—RUN NO. 6; ANNEALED AT 1967 DEGREES FAHR.; 43 HOURS; PACKED IN WHITE SEA SAND — × 100

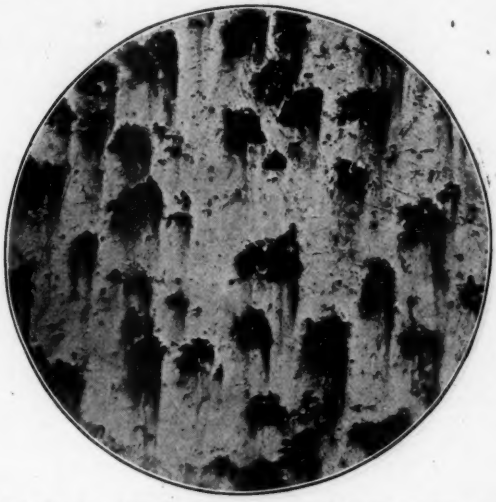


FIG. 8—RUN NO. 10; ANNEALED AT 1562 DEGREES FAHR.; 28 HOURS; PACKED IN WHITE SEA SAND — × 100

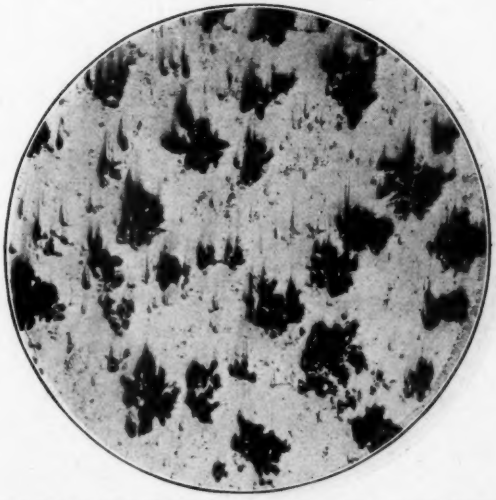


FIG. 9—RUN NO. 7; TEMPERATURE OF ANNEAL, 1634 DEGREES FAHR.; 32 HOURS; WHITE SEA SAND — × 100

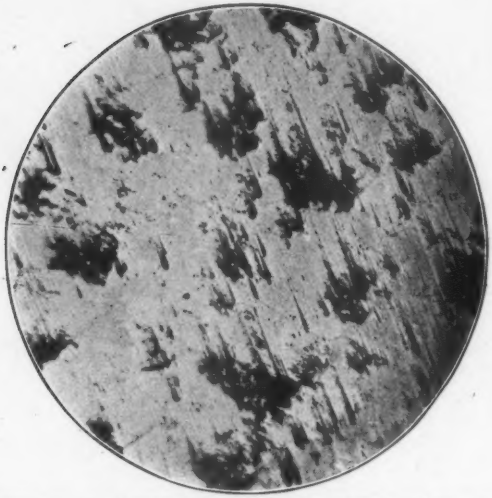


FIG. 10—RUN NO. 12; ANNEALED AT 1724 DEGREES FAHR.; 31 HOURS; PACKED IN WHITE SEA SAND — × 100

FIG. 11—RUN NO. 8; ANNEALED AT 1751 DEGREES FAHR.; 30 HOURS; PACKED IN WHITE SEA SAND — × 100

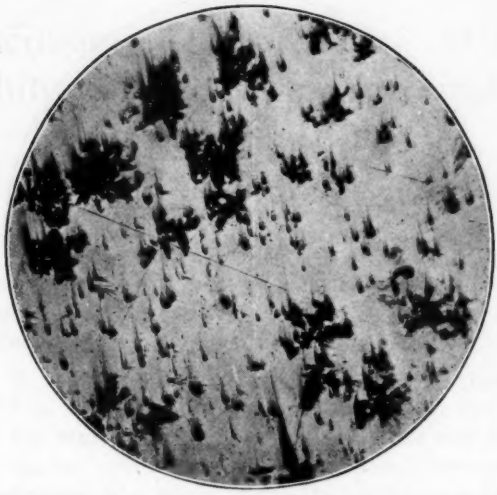


FIG. 12—RUN NO. 11; ANNEALED AT 1778 DEGREES FAHR.; 31 HOURS; PACKED IN WHITE SEA SAND — × 100

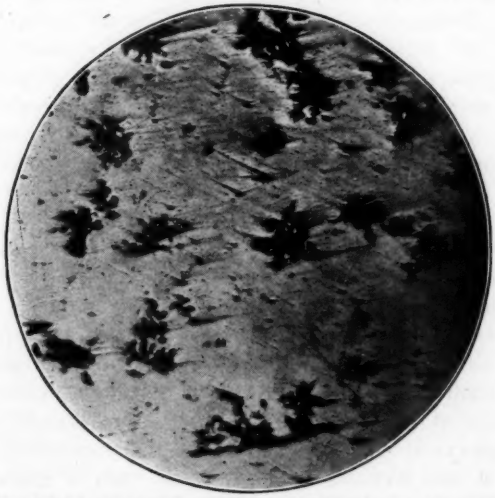


FIG. 13—RUN NO. 9; ANNEALED AT 1832 DEGREES FAHR.; 34 HOURS; PACKED IN WHITE SEA SAND — × 100

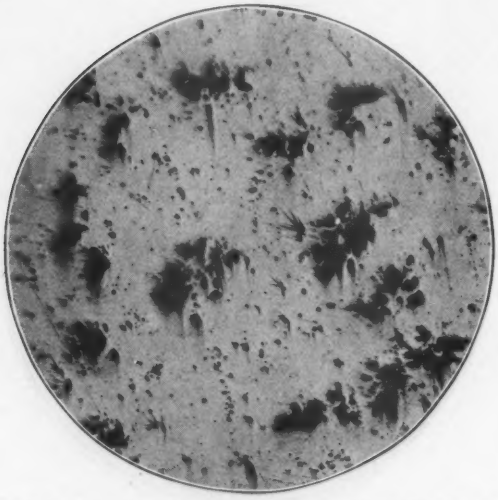


FIG. 14—RUN NO. 14; ANNEALED AT 2012 DEGREES FAHR.; 32 HOURS; PACKED IN WHITE SEA SAND — × 100

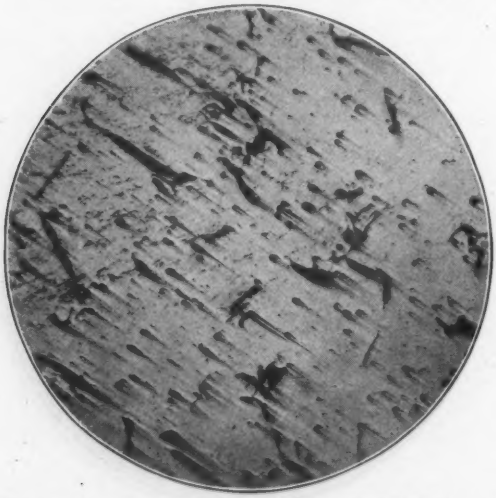


FIG. 15—RUN NO. 13; ANNEALED AT 2102 DEGREES FAHR,; 31 HOURS; PACKED IN WHITE SEA SAND — × 100

Discussion—Temperature of Graphite Particles in Graphitization of Cast Iron

D. M. SCOTT.—I would like to find out if the cooling rate is the same?

E. J. P. FISHER.—Yes sir, I took particular care about that, to see that the furnace was stopped in thirty hours and that the heat was decreased gradually; it was the same rate of cooling.

H. W. HIGHRITER.—In discussing Mr. Fisher's paper, I think it would be very fitting to congratulate him on the contribution he has made to the literature on malleable cast iron. The results he has obtained are very excellent confirmation and supplementation of a paper which Mr. Archer and Col. White presented. Mr. Fisher has elaborated on the subject and shown more completely the way in which the shape of the temper carbon nucleii changed with increasing temperature. We have at the Eastern Malleable research department for sometime been judging the temperature at which castings were annealed by the shape of the tempered carbon nodules. Those in which, for example, as in Figs. 13 and 14, there is a somewhat scattered tempered carbon nucleus we call star shape, while if the carbon nodule is spherical and apparently quite solid, we assume with, I think, fairly good justification, that it was carried out at a relatively low temperature. The reason that we have assigned for this is one in which the resistance of the matrix owing to the temperature resists the accretion of these carbon particles because of its lack of plasticity. As the temperatures increase, it is natural to assume that the plasticity of the theoretic matrix is increased and would therefore tend to allow the carbon or tempered carbon nodules to assume more nearly their crystalline shape or the shape of crystalline graphite, which is plate like. We have assumed that as the temperature increased, the mobility of the medium was increased,

and therefore there was less resistance offered by the matrix to allowing temper carbon to form its natural crystalline shape. Mr. Fisher has shown an apparent critical point somewhere in between 2000 and 2100 degrees Fahr. wherein this change was very rapid, and I think he has made a very interesting and very valuable contribution, and taken with Col. White's paper this morning, the literature on malleable cast iron is considerably augmented. I think they are to be congratulated.

The Influence of Temperature and Composition on the Graphitization of White Cast Iron

By A. E. White and H. E. Gladhill, Ann Arbor, Mich.

White cast iron when cooled from the molten state contains all of its carbon in the combined form. The combined form is of two possible types, the one a carbide of iron, Fe_3C, cementite and the other a solution of this carbide of iron in iron. Collectively these two constituents at temperatures above the critical range, are not the ones constituting a condition of equilibrium, at least when small amounts of impurities such as silicon are present. The equilibrium products at such temperatures are a solution of carbide of iron in iron and graphite. The amount of combined carbon present for an equilibrium condition in a white iron undergoing graphitization is essentially on the iron-carbon system dependent upon temperature and kind and quantity of metalloids such as silicon, sulphur, etc. If after equilibrium for a given temperature is established, the iron is cooled at a sufficiently slow rate through the succeeding lower temperatures down to and including the critical range, the remaining combined carbon will be precipitated as graphite,

FIG. 1—WHITE CAST IRON MAGNIFICATION 100

FIG. 2—CAST IRON ANNEALED 5 HOURS AT 1600 DEGREES FAHR., MAGNIFICATION 100

and the resultant constituents will be iron and graphite. The photomicrographs in Figs. 1 to 4 illustrate the changes which take place during such a process.

The present paper is primarily a study of the influence of temperature and composition on the time required to produce equilibrium conditions and of the cooling rates necessary to produce equilibrium under the above mentioned circumstances. The mode of procedure involved the heating of the samples of iron quickly to the desired temperature in a heavily insulated wire-wound electric furnace, holding the irons for varying

FIG. 3—CAST IRON ANNEALED AT 1600 DEGREES FAHR. UNTIL EQUILIBRIUM WAS ESTABLISHED—MAGNIFICATION 100

TABLE I

Analyses of White Iron ,

Type	Total carbon	Silicon	Manganese	Sulphur	Phosphor less than	Received from
Low carbon, low silicon.....	2.35	0.60	0.17	0.041	0.20	Saginaw Malleable Iron Co.
Low carbon, high silicon....	2.45	0.90	0.25	0.050	0.20	Albion Malleable Iron Co.
Medium carbon, medium silicon	2.70	0.82	0.21	0.050	0.20	

lengths of time at the given temperatures and then quickly cooling them. The irons thus treated were then analyzed for total and graphitic carbon (the total combined carbon was determined by difference). When the amount of combined carbon was found to undergo no further change, equilibrium was considered to have been established.

Three compositions of white iron were used. Their analyses and description are given in Table I.

Equilibrium studies were made for the conditions at temperatures ranging from 1800 to 1400 degrees Fahr. The data, are given below in Table II.

The data is also presented in graphical form in Fig. 5. The photomicrographs in Figs. 6 to 10 illustrate the equilibrium conditions at the various temperatures.

In order to determine the equilibrium cooling rates for the iron containing 2.70 per cent carbon and 0.82 per cent silicon, samples of this composition were heated in an electric furnace for a sufficient length of time to establish equilibrium at the temperature used, and then cooled through a 100 degrees Fahr. range at varying rates. They were then examined both chemi-

Table II

Temperature Degrees Fahr.	Time in Hours and Combined Carbon in Per cent Low carbon and High silicon	Medium carbon and silicon	Low carbon and silicon	
1800	4 or less	8	10	Time required to produce equilibrium
	1.19	1.21	1.25	Combined carbon for equilibrium
1700	5	15	20	Time required to produce equilibrium
	1.08	1.10	1.09	Combined carbon for equilibrium
1600	20	50	60	Time required to produce equilibrium
	0.88	0.84	0.89	Combined carbon for equilibrium
1500	35	72	130	Time required to produce equilibrium
	0.64	0.64	0.70	Combined carbon for equilibrium
1400		270		Time required to produce equilibrium
		0.49		Combined carbon for equilibrium

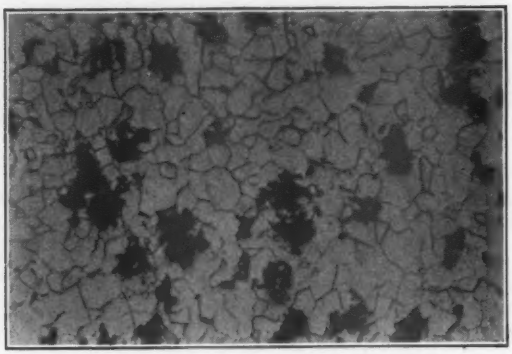


FIG. 4—COMPLETELY ANNEALED MALLEABLE IRON ETCHED IN PICRIC ACID. MAGNIFICATION 100

cally and metallographically. The maximum cooling rates thus established for the ranges of temperature from 1700 degrees to 1300 degrees Fahr., are given below in Table III.

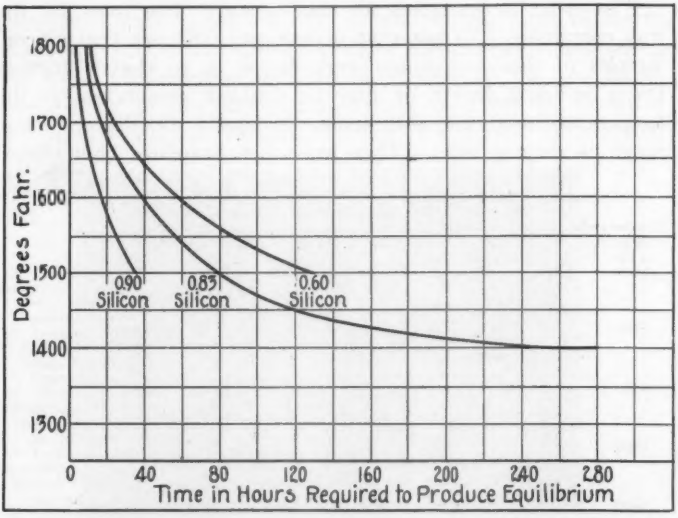


FIG. 5—CURVE SHOWING THE INFLUENCE OF TEMPERATURE AND COMPOSITION ON THE TIME REQUIRED TO PRODUCE EQUILIBRIUM CONDITIONS

TABLE III

Temperature Range		Cooling rate in degrees Fahr. per hour	
Degrees Fahr.	Degrees Cent.	Degrees Fahr.	Degrees Cent.
1700—1600	927—870	30	16.5
1600—1500	870—815	25	14.0
1500—1400	815—760	10	5.5
1400—1300	760—705	5	2.8

Extensive cooling rates were not carried out on the other two grades of iron but enough were run to establish the fact that by increasing the silicon content, increased cooling rates were possible. The cooling rates were carried no lower than 1300 degrees Fahr. (705 degrees Cent.) since in our opinion the solubility of carbon in iron becomes zero at the temperature existing at the lower critical point.

Change in Solubility

As evidence on the pronounced change in solubility at the lower critical temperature, we submit the results of the experiments conducted at 1400-1410 degrees Fahr. (760-765 degrees Cent.) and at 1390 degrees Fahr. (755 degrees Cent.) The one temperature was just above, the other just below the lower critical temperature for the iron used. For the higher temperature the quantity of combined carbon determined in equilibrium was 0.49 per cent; for the lower temperature it should have been 0.0 per cent. At the lower temperature after 320 hours, the combined carbon had dropped to 0.13 per

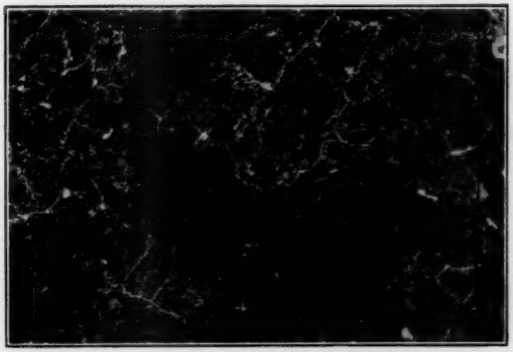


FIG. 6—EQUILIBRIUM CONDITION AT 1800 DEGREES FAHR. MAGNIFICATION 100. ETCHED IN PICRIC ACID

FIG. 7—EQUILIBRIUM CONDITION AT 1700 DEGREES FAHR. MAGNIFICATION 100. ETCHED IN PICRIC ACID

cent and there is no reason to believe it would not have gone to 0.0 per cent had the heating cycle been continued longer.

Conclusions

Several quantitative deductions with regard to the influence of composition and temperature on the annealing of white cast iron, based on the data presented, are submitted:

1. By increasing the silicon only a few tenths of a per cent, a decrease of more than 50 per cent in the annealing time at the lower temperatures is possible. See Fig. 5.

FIG. 8—EQUILIBRIUM CONDITION AT 1600 DEGREES FAHR. MAGNIFICATION 100. ETCHED IN PICRIC ACID

FIG. 9—EQUILIBRIUM CONDITION AT 1500 DEGREES FAHR. MAGNIFICATION 100. ETCHED IN PICRIC ACID

2. For any composition of white iron lying within the limits of those investigated it is possible to predict the length of the "at heat" period for any temperature above the critical range. See Fig. 5.

3. The maximum cooling rate for an 0.80 silicon iron is given. See Table III. This rate may serve as a basis for other irons, the cooling rate being increased by a higher silicon contact and decreased by a lower per cent of silicon.

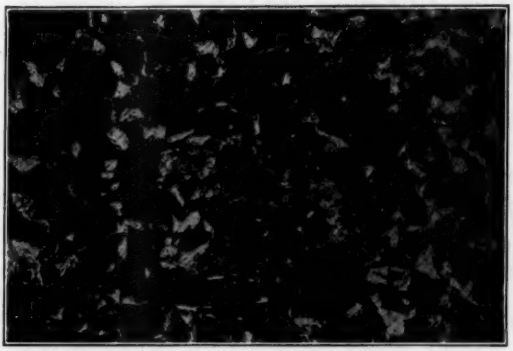


FIG. 10—EQUILIBRIUM CONDITION AT 1400 DEGREES FAHR. MAGNIFICATION 100. ETCHED IN PICRIC ACID

A European View of the Malleable Problem

By T. Levoz, Auxonne, Cote d'Or, France

The position of the malleable castings industry on the continent of Europe was considered at length at the joint French and Belgian foundry congress held at Liege at the end of last September. The following passages embody the principal opinions expressed:

"The first aim should be to interest all our French, English and Belgian confreres in the institution of systematic experiments, which should all be carried out in a uniform manner so that they may be compared and the results intercommunicated.

"Permanent intercourse also should be maintained with our American confreres, and steps should be taken to insure the regular exchange of communications between the various associations.

"The second aim should be to interest the leading French, English and Belgian scientists in the investigation of the laws governing the manufacture of malleable iron, chiefly in regard to the effect of the silicon and that of the sulphur, on the condition of the carbon both at the two stages and on graphitization of the carbon.

"In this way we shall attain the position long ago reached by our American confreres; that is to say we shall be able to compete successfully with cast steel both as regards quality and price, thus preventing the disappearance of an industry which was formerly flourishing but which is declining because European foundrymen work neither scientifically nor economically and are lacking in co-operation.

"Before the war the average cost price of an American manufacturer of malleable iron turning out agricultural machinery castings was 25 centimes per kilogram, (about 2.4 cents per pound). Making all due allowances, there is no reason why we should not attain the same results."

Since then the Belgian and French technical foundry associations have met and decided to form a special commission

*Contributed through the courtesy of the Association Technic de Fonderie de France.

for the purpose of carrying into effect the wishes expressed at Liege.

Special attention has been excited by the exceptional results obtained by American foundrymen as regards the quality of the metal which, it appears, ordinarily shows the following mechanical characteristics:

Resistance: 30 to 50 kilograms per square millimeter,
Elongation: 5 to 25 per cent measured over 50 millimeters,

as compared with 30 to 40 kilograms and 2 to 4 per cent in European practice. Here there is a wide gap, and in order to bridge it it is not enough merely to agree to establish uniform methods of experiment. What is required is an agreement to establish a single mode or method of production capable of supplying a metal suitable for the manufacture of good test pieces corresponding in structure to castings usually required in malleable iron.

What is a Suitable Metal?

I am considering here only the production of the metal, which is the starting point of all manufactured castings, for when the metal is suitable three-fourths of the work of successful casting has been done. What, then, is to be understood by "suitable" metal? In general foundry practice (ordinary cast iron, malleable cast iron or cast steel) suitable metal is understood to be that which when cast flows over the sand on contact with it without attacking the organic matter. It is, of course, understood that the metal must combine the mechanical conditions and characteristics required. In order that the metal shall flow over the sand its iron oxides must previously be reduced, and if they are not reduced completely it is preferable that they should be in the ferric rather than the ferrous state.

Many foundrymen are imbued with the idea that a metal cast too hot prevents the scraping of the sand on contact, but this is a mistake.

Of course, apart from the question of pipes and shrinkages, a perfectly deoxidized metal may be cast at maximum temperatures without attacking the organic matter of the sands generally employed in foundries—for ordinary cast iron, malle-

able iron or cast steel. The error is chiefly noticeable among founders of cast steel, who often regard a dazzling metal as being too hot, even when it is greatly superoxidized, sometimes to the point of solidifying almost instantaneously when it is decanted into the ladle.

The purpose of these remarks is merely to point out to founders of malleable iron that their interest is not merely to study the part played by the carbon, silicon, manganese, sulphur and phosphorus, and that they have invariably neglected the part played by the principal factor—the iron oxide—which is the source of all their troubles and disappointments.

It is, in fact, the greater or less degree of oxidation of the iron that governs the temperature of the bath and, consequently, its composition.

Generally, whether it is a question of ordinary cast iron, of malleable iron or of cast steel, in which the oxidation of the iron plays the most important part, it is necessary to have the initial metal at the maximum temperature so as to facilitate all the reactions necessarily arising from the presence, in larger or smaller quantities, of the ferrous or ferric oxides.

Now the former absorbs heat calories in order to be reduced in presence of the carbon while the latter release them. This is why it was stated earlier in the paper that it was preferable for the unreduced oxides in the metal to be in the ferric state.

It is easy to determine the presence of either of these oxides in liquid metal containing only iron and carbon, with a minimum of silicon and manganese.

Metal containing ferrous oxides boils violently in presence of carbon and liberates graphitic carbon at the moment of solidification because all boiling causes cooling.

Examine the worn rails on the P.L.M. tracks; they are full of blisters flattened out at the rolling mills. These blisters contain graphite and unreduced ferrous oxides. This is a striking example of cooling produced by boiling; ferrous oxides and carbon.

Selection of the Furnace

To obviate this capital defect in the production of iron for malleables—a defect essentially of a practical nature—it is absolutely necessary that the first stage metal should be produced in apparatus providing maximum temperatures without the formation of ferrous oxides.

Foundrymen have available, the crucible which was the first system of manufacture employed. It requires mixtures of good quality, and as the materials composing these are not exempt from rust, ferrous oxides are developed during fusion. To remedy the bad effect so produced the temperature of the furnace must be increased. This causes an excessive consumption of coke or coal, the result of which is a prohibitive cost of production.

The cupola furnace, which is mostly used, is the producer par excellence of ferrous oxides. It is a barbarous principle of fusion, especially for the production of iron for malleable castings. To be able to cast the metal at all suitably maximum temperatures must be obtained; the consumption of coke must be increased, as must also the silicon content. Hence the common practice of forcing the silicon addition in order to be able to make exceedingly thin castings.

The reverberatory furnace undoubtedly is the apparatus which least occasions the formation of ferrous oxides. However, it also is at the mercy of rusty materials and of other oxidizing tendencies. If the Americans employ it with success in producing malleable iron of great elongation and strength, this is because they have succeeded by practical methods in obviating the formation of ferrous oxides by effecting the fusion in a carbon oxide atmosphere. Unfortunately the employment of reverberatory furnaces is practicable only for mass production, and the consumption of malleable castings has developed less in Europe than in America.

If European foundrymen had at their disposal a cupola obviating oxidation of the iron it is evident that such an apparatus would be the ideal method of producing malleable iron, subject to the condition, however, that it should effect fusion

at the highest possible temperature.

Four years ago, in the *Fonderie Moderne,* the writer drew attention in this connection to a small cupola with two tuyeres placed at different heights, with which he had obtained good results in a malleable iron foundry in Belgium.

Fusion by gases is less to be recommended, because it is almost indispensable to produce oxidizing flames in order to secure the high temperatures required. In this connection it would be preferable to effect fusion by the pulverized (slack) coal system, provided regenerators capable of heating the air of combustion to over 600 degrees Cent. are employed.

This applies also to the use of heavy oils, and in this case it is also necessary and indispensable to have a furnace specially arranged for an adequate distribution of the heat without oxidizing the iron.

Electric Furnace Experiments

The converter and the electric furnace remain. The latter, when employed as a fusion apparatus, is also the mercy of the pig iron, scrap or other rusty waste; the operation must be carried to the point of complete deoxidation, and even at this point it is difficult to obtain uniform carburization.

Recently the author made an experiment to see to what extent a metal fused electrically, obtained from highly oxidized scrap, and containing also 25 to 30 per cent of turnings agglomerated by the oxidation of the atmosphere, could be carburized and poured. Notwithstanding the fact that the slag was well composed and the temperature raised to the extreme limit, uniform carburization could not be obtained, and the metal, which appeared hot while in the furnace, solidified on being poured into the ladle because it still contained ferrous oxides which in spite of everything had not been reduced.

The only method of producing malleable iron electrically of uniform quality is by starting with scrap or a mixture of scrap and pig in a coke or coal fired furnace. The metal thus obtained is poured into a closed electric furnace where it is finished, but for this purpose a powerful and cheap supply of electricity must be available. One foundry in the Hautes-Py-

renees, however, to which the writer is adviser, works on this system and obtains excellent results. It even provides foundrymen with pig iron produced by this method, which when remelted in cupola, crucibles or other furnaces, gives better results than blast furnace pig, because it contains a minimum of graphitic carbon and a minimum of sulphur.

The German Method

In my opinion the only method of competing successfully with cast steel in Europe is to produce malleable iron on the same system as cast steel. The Germans, who have long specialized in the manufacture of cast steels and malleable iron, clearly recognized this, and since 1905 they have been making malleable by melting hematite pig in the cupola, afterward transferring it to the bessemer converter in a liquid state in order to desiliconize it and pour into the molds a metal which is merely carburized.

Three Germans introduced this method of manufacture into France, with some success. This was at Colombier Fontaine, Doubs, about 1911. They did not succeed, however, in competing against cast steel, which they were obliged to produce also to supply the requirements of their clients. This was because this process was far from perfect.

As a result of the sequestration of this establishment shortly after the declaration of war (January 1915) the writer leased the factory and was thus in a position to acquaint himself with the quality of the metal produced.

It was far from suitable for the uniform production of good malleable iron. A sample was taken from the numerous gates found in the works and analyzed, its composition being as follows:

	Per Cent
Combined carbon	2.80
Graphite carbon	0.50
Manganese	0.30
Silicon	0.80
Sulphur	0.06
Phosphorous	0.09

The ordinary bottom-blown bessemer converter is not at all suitable for this kind of work, as it produces ferrous oxides while it is desiliconizing the metal. The result is that the white

pig bath is obtained too cold, which causes the formation of graphitic carbon at the moment of solidification.

Without even trying this process, the writer decided not to employ it. In this he was well inspired for he found that the molders who had formerly worked with the Germans ran like hares to fill the molds placed at a maximum distance of 50 meters from the converters, although the metal was much too hot and fluid.

When asked the reason for this, they replied that when the Germans were there they were always made to hurry to cast the malleable iron, "otherwise they would not have produced a good casting."

If from time to time a good casting was produced this was owing to the metal bath in the cupola having been overheated.

In 1915 the author started working scrap metal in the cupola, transferring it by means of a ladle suspended from the crane to a side-blown converter with D-shaped section, which had been installed by the Germans for the manufacture of cast steel. According to the men who had worked with the Germans, the metal we were producing was much hotter and more fluid. It was no longer necessary for them to scurry like hares to fill the molds. They found also that we turned out few spoiled castings, whereas the Germans used to have 20 to 30 per cent.

The composition of the metal delivered from the converter was as follows:

	Per Cent
Combined carbon	2.340
Graphitic carbon	0.200
Manganese	0.440
Silicon	0.750
Sulphur	0.101
Phosphorus	0.082

The higher sulphur content was due to the quality of the coke used during the war. The Germans used coke which contained less than 10 per cent of ash and little or no sulphur. However, when the metal placed in the converter was too cold, or when, for any other reason, the desiliconization was accompanied by the formation of ferrous oxides, violent boiling took place as the metal flowed into the ladles, and the slag, which

was extremely fluid, was carried into the molds along with the metal. It was then necessary to put a small addition of aluminum in the ladles to calm the bath and obviate blistering as much as possible.

Fractures of the reheated castings then showed a black structure similar to American castings. The castings were, however, exceedingly malleable, and they bent even better than those having a granular structure.

The mechanical tests of this metal gave the following results: Resistance, 35 kilograms per square meter; elongation, 5 per cent measured over 100 millimeters.

Its chemical composition was:

	Per Cent
Combined carbon	0.100
Graphitic carbon	1.200
Manganese	0.330
Sulphur	0.101
Phosphorus	0.082
Silicon	0.987

The same metal without aluminum addition had a granular structure, from which it may be deduced that the presence of the aluminum for the purpose of reducing the ferrous oxides immediately before solidification favored the formation of hardening carbon or secondary graphite.

At this time it seemed that in order to obtain a more uniform metal, the metal from the converter ought to be passed into a furnace heated to 1500 degrees Cent., either by the gases, or by heavy oils or electricity, and that it ought to have a small admixture of metal taken from the cupola.

A French Triplex Process

In 1915 the author registered a patent in France for this process, and it appears that about the same time W. G. Kranz took out a similar patent in America for a "triplex process for making electric furnace malleable castings." The writer subsequently recognized that it was undesirable to reintroduce metal produced by the cupola, which favors the formation of graphite at the moment of solidification. The converter was installed with cylindrical crucible and tuyeres arranged tangentially to a circle of fixed diameter. A hotter and more liquid metal was obtained, because ferric oxides were formed at the surface

of the metal bath and there stimulated the desiliconization and, to a certain extent, the decarburization, while maintaining the bath at the necessary temperature for casting without any aluminum addition.

When the operation is carried out normally in this converter the reddish vapors surrounding the flame do not appear until after desiliconization and at the very beginning of decarburization, increasing in proportion as the latter advances. The vapor ought not to cease on the first break through of the flame; it ought to continue until the second break and issue abundantly at the end of the blow.

If the reddish vapor is plentiful at the outset of the operation and diminishes or ceases on the first break through of the flame, ending with a rather bluish vapor, this indicates that the operation has not been effected normally.

In the first case, the adjustment for obtaining the malleable iron has been well determined, while in the second case it has been faulty, the result being variations in the quality of the metal. It then occurred to the writer to pass this metal, still taken in a very hot and fluid state, into a furnace heated to 1550 degrees Cent., either by the gases, heavy oils or pulverized coal, but preferably by electricity, merely for the purpose of deoxidizing, desulphurizing and regularizing the carbon, silicon and manganese contents.

Under the blowing conditions in the first case there is formation of ferric oxides which obviate the ebullitions which are so detrimental to obtaining suitable metal, and under these conditions the operation of adjustment in the furnace is easily effected.

In the second case ferrous oxides are formed, causing ebullitions and rendering the final operation of the furnace more complicated. It is necessary to overheat the metal bath in order to bring about a really effective reduction.

It was after coming to these conclusions that the author finally took out a French patent on this method of manufacture. An English patent also has been granted.

In order to work this triplex process accurately and obtain

the metal desired it is essential that the following apparatus should be employed:

1.—A cupola with combustion zone distinctly separated from the zone of fusion in which only reducing gases circulate;

2.—A side-blown converter which evacuates the slag as fast as it is formed, insuring the formation of ferric oxides which secure the fluidity of the metal for the purpose of preventing the formation of graphitic carbon on solidification.

3.—An electric furnace which insures the proper distribution of heat with a minimum expenditure of electric power; or a heavy oil furnace, if electric power is not available.

The average composition of the metal obtained is as follows:

	Per Cent
Combined carbon	2.30
Graphitic carbon	traces
Manganese	0.30
Silicon	0.40
Sulphur	0.03
Phosphorus	0.05

This metal, being obtained very hot and freed from oxides, flows over the sand and produces castings which look clean and are without the defects usually found in ordinary malleable castings.

It is noteworthy that castings of the most complicated form may be left to cool in the molds with little risk of dents, cracks, flaws, fractures or other defects. The constant use of a reheating furnace, always alight to take the castings which are still red when stripped, is thus obviated.

No distinction is made in the silicon content whether thick or thin castings are made, which enables a metal only slightly charged with graphitic carbon to be obtained; and in view of the absence of oxides the latter is distributed uniformly throughout the mass in a pulverulent state, preventing the formation of cavities which cause breakages of continuity and are destructive of elongation and resistance.

The reheated metal has the following composition:

	Per Cent
Graphitic carbon disseminated throughout the mass in the pulverulent state	0.90
Manganese	0.25
Silicon	0.40
Sulphur	0.03
Phosphorus	0.05

This metal gave the following results under mechanical tests: Resistance, 40 kilograms per square millimeter; elongation, 15 per cent measured over 100 millimeters.

A metal obtained by the same process is capable of producing all castings, whether thick or thin, with the following composition:

	Per Cent
Combined carbon	2.00
Manganese	0.40
Silicon	0.25
Sulphur	0.05
Phosphorus	0.03

Reheated for 72 hours in a dormant furnace at a constant temperature of 850 degrees Cent. without ores, the results under mechanical tests were: Resistance, 60 kilograms; elongation, 12 per cent measured over 100 millimeters.

In this process the pig destined for conversion was obtained synthetically in the nonoxidizing cupola by the intimate mixture of 10 to 12 per cent of ferrosilicon and miscellaneous scrap and waste.

At the present price of these materials with coke at 140 francs per ton, coal at 85 francs per ton, and electric power at 0.40 francs per kilowatt-hour, malleable iron castings or indirect steel can be produced at less than 100 francs per 100 kilograms. (About 4½ cents a pound at current exchange.)

As has been shown above the metal produced by this process possesses mechanical qualities almost equal to those of cast steel, but with the important difference that the castings are much cleaner in appearance.

These cast steels, it is true, give the following results under mechanical tests: Resistance, 40 to 50 kilograms and more per millimeter; elongation, 15, 20, 25 and even 30 per cent over 100 millimeters. The castings do not always have such a good appearance and they may harbor hidden defects arising from bad manufacture. A manufacturer who employs the triplex process can produce simultaneously either direct cast steel, indirect cast steel, malleable iron or special steel or tempered castings.

Use of Carbon Dioxide Recorders for Controlling Combustion of Powdered Coal

By D. M. Scott, Rochester, N. Y.

The success that has attended recent installations of powdered coal burning equipment in a number of malleable iron foundries will no doubt result in this fuel being more generally used in this industry for both melting and annealing. As the success or failure with powdered coal depends largely on the accuracy of the coal feed and correctness of the mixture a description of certain devices used for indicating and maintaining these conditions should be of interest.

In the malleable foundry of the T. H. Symington Co. at Rochester, N. Y. powdered coal has been used for firing the annealing ovens for the last 12 years and during the past year it has been successfully applied to the melting furnaces. The change from hand firing of the air furnaces to powdered coal resulted in a decrease of from 20 per cent to 50 per cent in the costs of repairs, fuel, and labor. While these reductions are most satisfactory the possibilities of greater economies are apparent from the results obtained with occasional heats run under ideal conditions.

Powdered coal has certain characteristic physical properties which call for special methods of handling. When mixed with a certain amount of air it can be treated in many respects as a gas. Certain conveying or transportation systems take advantage of this characteristic by aerating the powdered coal with a certain percentage of air and forcing the mixture through piping to the furnaces or ovens. Powdered coal at rest in the furnace receiving hopper displays some of the characteristics of a fluid in that it will flow and will yield to a slight pressure. In certain types of feeders the coal flows by gravity through an orifice into a current of air. Unfortunately powdered coal does not possess either of these characteristics with the necessary

consistency and it is therefore essential that feeders and mixers for powdered coal be carefully designed with due regard for these somewhat erratic properties. When aerated the particles of coal being heavier than air develop a different velocity under certain conditions. When in a mass the coal will at times develop sufficient friction between the particles to give a high angle of repose. It is for these reasons that the conditions necessary for perfect combustion, a constantly uniform and complete mixture of coal and air, can be obtained only by intelligently designing and operating the feeding and mixing equipment. Where combustion takes place in a large chamber a certain amount of fluctuation in the ratio of coal and air is not so detrimental but in a melting furnace where a high flame temperature is essential the thermal efficiency will be decidedly increased if the air and coal ratio is uniformly maintained within close limits of accuracy.

The standard method of withdrawing or feeding powdered coal from a hopper is by the use of horizontal screws placed at the bottom of the converging hopper side sheets. While these screws in our experience seem to feed coal more steadily than the gravity or syphon equipment, there is still a certain amount of fluctuation in the rate of feeding. In addition to this fluctuation there are certain less frequent though more serious interruptions in the rate of coal feed, such as the flushing of an excess amount of coal or the arching or bridging of coal in the hopper which prevents the coal reaching the feed screws. Failure to maintain the necessary uniformity in coal feed has undoubtedly been the principal reason for previous lack of success in powdered coal installations.

In the foundry referred to one man regulates the burners on 21 80-ton annealing ovens and as the distance between the first and last oven is 500 feet the coal feed may be interrupted for some time before the oven tender might locate the trouble. It was with a view to locating these interruptions immediately as well as maintaining the necessary constant mixing of coal and air that carbon dioxide recorders were applied to the annealing ovens. The success of the recorders on the annealing

ovens led to their application to the melting furnaces where they are now used to maintain a closer control of the combustion.

The use of carbon dioxide recorders in regulating combustion is not new but they have not been used as extensively as their theoretical necessity would seem to warrant. The reason for this perhaps lies in mechanical difficulties which have been experienced with certain earlier types of recorders. For the equipment herein described several makes of recorders were installed experimentally and one of these was found to give quick and accurate analyses of the flue gases and to require a little more care and attention than an electric pyrometer. Undoubtedly other makes of instruments can be obtained which will give equally satisfactory results but the urgent necessity for the regular use of these instruments makes it seem inadvisable for us to continue our experiments any further at this time.

Described briefly, the carbon dioxide recorder is an instrument that automatically takes a measured sample of flue gas and registers on a chart the percentage of carbon dioxide. The sample is reduced to a constant temperature and pressure after which it is measured and then passed through a caustic potash solution which removes the carbon dioxide. The loss in volume represents the percentage of carbon dioxide and this is recorded on the chart. Flue gases are drawn continuously through the sampling tube at a velocity of 60 feet per minute more or less depending upon the size of the gas line, so the sample will always be the same as the flue gas at the time of sampling. Twenty-four of these analyses are made each hour so the chart shows a practically continuous record of the carbon dioxide content.

The value in determining the carbon dioxide content as is generally known lies in the fact that it indicates the proportion of air to coal, completeness of combustion and presence of furnace leaks. For every furnace or fuel there is a certain mixture of air and fuel that gives the best obtainable results, whatever they may be, and whenever the proportion of air exceeds or falls below this correct amount there are certain losses of more or less important character. The only

accurate guide as to when this correct mixture of air and fuel is being used is by constant analysis of the flue gases.

In burning powdered coal practically complete combustion can be obtained whereas when lump coal is burned on grates only partial combustion is accomplished except through an elaborate furnace construction. If coal were pure carbon the chemical formula representing its complete combustion would be 0.64 pounds of coal plus 100 cubic feet of dry air at a temperature of 75 degrees Fahr. (comprised of 21 feet of oxygen and 79 feet of nitrogen) which would give 21 feet of carbon dioxide and 79 feet of nitrogen. In this case the volumetric percentage of carbon dioxide is 21 per cent. Theoretically if the carbon were increased the products of combustion would contain carbon monoxide as well as carbon dioxide and the percentage of the latter would be less than 21 per cent. In the same way an excess of air would reduce the carbon dioxide below 21 per cent on account of the presence of free oxygen. In other words 21 per cent represents the theoretical maximum carbon dioxide content with pure carbon. As coal contains oxygen and hydrogen as well as pure carbon the carbon dioxide content with perfect combustion cannot reach 21 per cent. W. Trinks, in a recent article on flue gas analysis, gives 18.66 per cent carbon dioxide as the calculated point of perfect combustion of a Pittsburgh coal. With powdered coal from the same district our carbon dioxide recorders indicate that complete combustion is obtained when carbon dioxide reaches 19 or 19½ per cent. Therefore, if complete combustion is desired the coal and air mixture should be maintained at a ratio that will give a constant carbon dioxide content of about 19 per cent.

Assuming that excess coal is used to such an extent that the carbon dioxide content drops to 14 per cent through the presence of carbon monoxide in the flue gas. This represents a loss of about 10 per cent in the heat generated per pound of coal owing to incompleteness of combustion. If the 14 per cent carbon dioxide is due to excess air the loss represents about 6 per cent on account of sensible heat in the additional

flue gas at 1000 degrees Fahr. While we do not know what our average performance was before the installation of carbon dioxide recorders we feel safe in estimating that their use would have prevented the waste of at least 5 per cent of our coal had the oven tender always known the condition of the flue gases. With an average annual consumption of 10,000 tons of powdered coal for annealing this 5 per cent is equivalent to 500 tons which at $7.00 per ton represents an annual economy of $3500.00.

In addition to serving as a guide in maintaining economical combustion the carbon dioxide recorders act as a check on the oven tender's work, condition of the furnace with respect to leaks, and the operating condition of feeders and burners. They also give immediate warning when coal stops feeding which reduces excessive oxidation of annealing pots or castings where a muffle furnace is used. To prevent loss of time in correcting any serious condition, the indicators were so constructed that an electric bell will ring when the carbon dioxide content drops below 16 per cent. The elimination of oxidation in the muffle has been most effective since free oxygen has ceased to occur in the combustion chamber. Inside the muffle the atmosphere now remains consistently between 10 and 30 per cent carbon monoxide whereas before the carbon dioxide recorders were functioning there was always a certain amount of carbon dioxide and oxygen in the muffle, both of which caused scaling of the castings.

For a battery of 21 ovens seven recorders are used. Each recorder is piped so that it can be connected with any one of six ovens which permits covering any oven under fire. The recorders cost around $400 each installed and the cost of operating them, including labor, charts, water, solutions, and maintenance runs about $7.00 per month per recorder. As mentioned before, the recorders will not get out of order if given ordinary care. They must, however, be handled by some one who understands their construction in a general way. The total amount of time required to take care of each recorder averages between ten and fifteen minutes daily. This

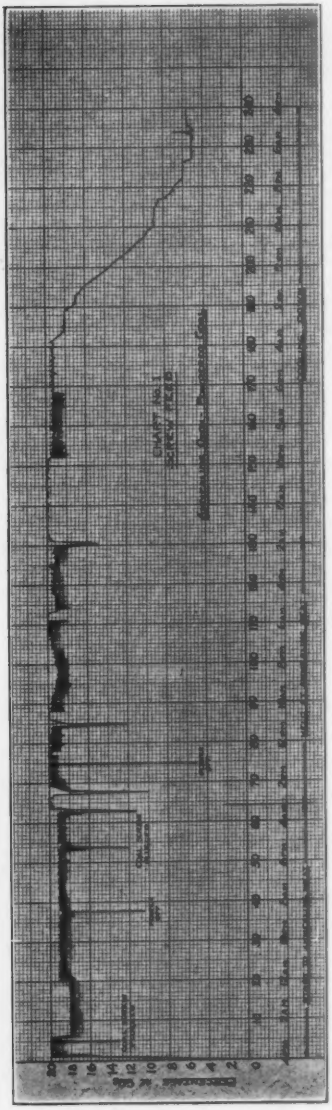


FIG. 1

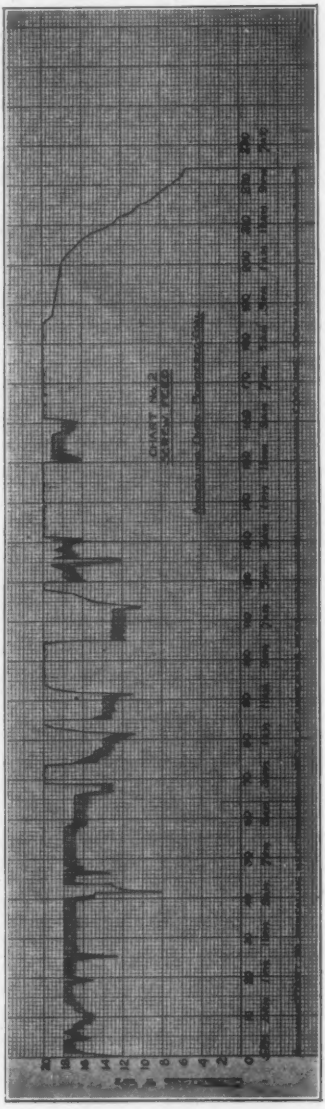


FIG. 2

work involves the daily changing of charts and filters. Between heats the sampling line must be blown out with compressed air and the recorder calibrated with atmospheric air. The caustic potash solution does not require renewal oftener than every two months. Water consumption with 3/4-inch sampling pipe is about 20 gallons per hour. It is advisable to make periodical checks on the recorder with an Orsat instrument although we have not yet found any appreciable error in the recorder readings.

Several typical carbon dioxide charts are illustrated. The recorder charts are circular and cover but 24 hours so several charts are required to show the complete record of an annealing heat which runs about two weeks. To facilitate reading of the heat records the charts have been transcribed to single straight line charts. On the annealing oven charts that part of the curve which represents the condition of flue gases during firing periods has been shaded. Between firing periods the ovens are sealed and the carbon dioxide content then indicates presence or absence of furnace leaks. The annealing oven charts represent combustion conditions with four distinct types of feeders: Horizontal screw, gravity, syphon and vertical screw.

The melting furnace charts show combustion records of a hand fired furnace and a screw feed powdered coal furnace. A great deal of difficulty was experienced in constructing a sampling tube that would stand the high temperatures of the powdered coal melting furnace. Quartz and alundum tubes proved unsatisfactory as they would develop leaks after two or three heats. The difficulty was finally solved by using two sampling tubes and collecting the samples from that part of the furnace where the gases were under pressure. Where this condition existed it was not necessary to have the sampling tube air tight. While the charge was being melted the gas samples were taken about six feet from the burners and after melting they were taken about midway between bridge walls.

Fig. 1 represents a good performance on a horizontal

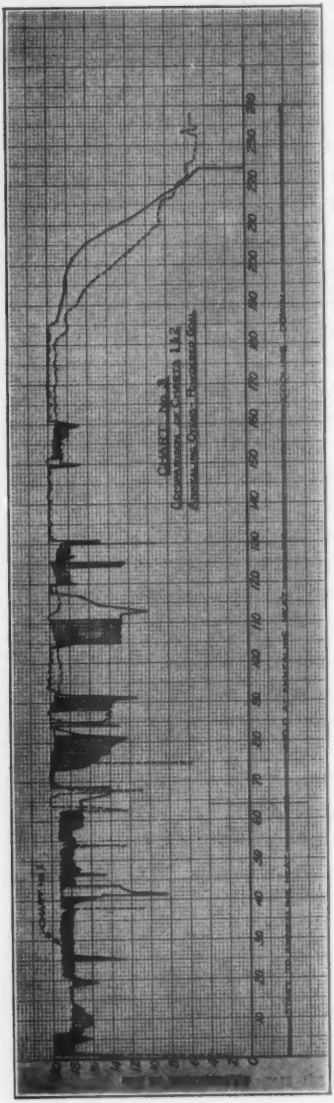


FIG. 3

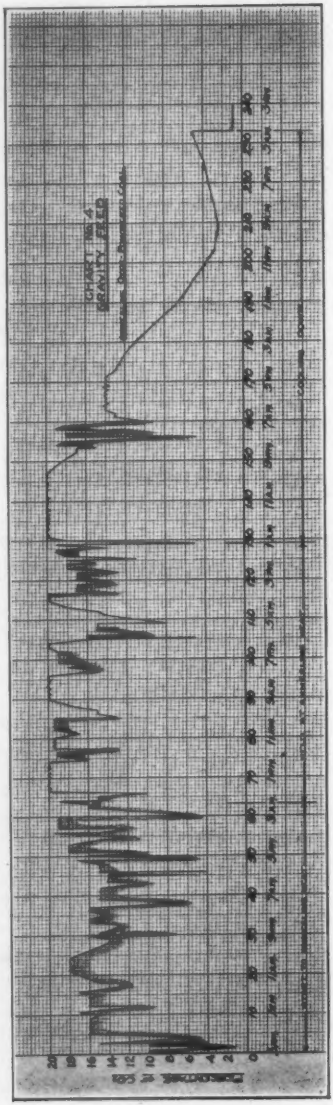


FIG. 4

screw feed annealing oven. The average carbon dioxide content during firing periods was about 19 per cent which is close to the maximum. Eight breaks in curve are shown. Two of these were due to coal screw plugging and two were caused by motor fuses blowing. Each of these interruptions caused the alarm bell to ring and the oven tender corrected the trouble in a few minutes. Without the recorder or signal these interruptions might have continued for some time. The other breaks in the curve occurred when firing was discontinued or started and were due to air getting into the oven.

The chart in Fig. 2 was made on the same oven as Fig. 1, all conditions being the same except that the operator was not permitted to see the recorder. He made a special effort to obtain as good a chart as No. 1 and while he succeeded in controlling his combustion more than was customary without flue gas information there was a noticeable difference between charts in Figs. 1 and 2. We were unable to get a chart that would represent a typical condition under the old method because the oven tender always discovered that the heat was being recorded and consequently gave the oven more than the usual attention.

The chart in Fig. 3 is a composite of those in Figs. 1 and 2 and the shaded area between the two curves represents the difference in the carbon dioxide content during firing periods where these periods coincided as to time. The shaded area represents an avoidable loss in thermal efficiency.

The chart in Fig. 4 shows clearly the wastefulness of a gravity feed burner. During the annealing heat recorded every effort was made to maintain a good mixture but it was not possible to even approximate screw feed results. We estimate roughly that had this heat been run with a uniform 18 per cent carbon dioxide there would have been three thousand pounds of coal saved.

The chart in Fig. 5 shows the performance of a recently developed syphon feeder operated alternately with a horizontal screw feeder. The syphon feeder was operated during day shift when it could receive the maximum attention. In this

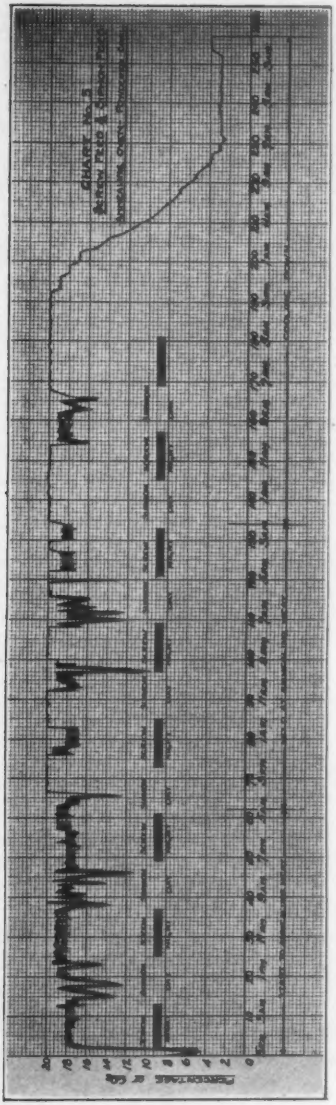


FIG. 5

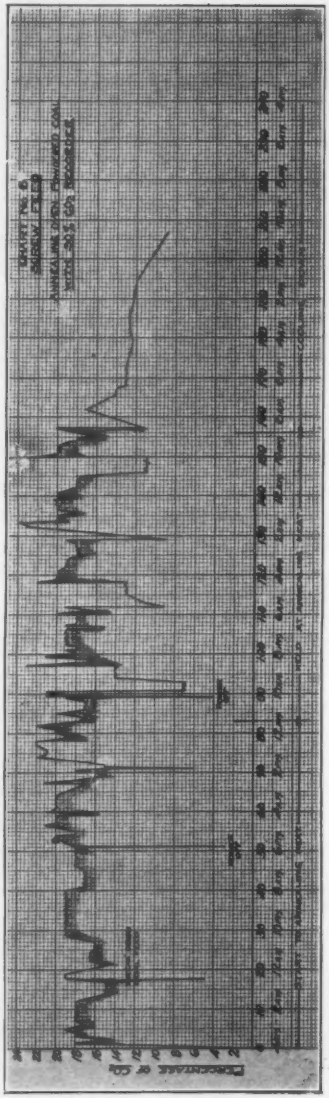


FIG. 6

case the carbon dioxide recorder furnished all the necessary evidence to condemn the syphon feeder.

The chart in Fig. 6 was made with a recorder having a 30 per cent range, the previous ones having been made with charts having the standard range of 20 per cent. During the holding period the carbon dioxide would exceed 20 per cent and it seemed desirable to record conditions at all times. The high percentages are largely due to reactions in the muffle such as the reduction of oxides by carbon monoxide.

The chart in Fig. 7 represents the first trial with a vertical screw feeder on an annealing oven. The carbon dioxide content was intentionally kept low as the condition of the oven required a lower flame temperature. This condition coupled with the oven tender's unfamiliarity with this type of burner resulted in an irregularity in the carbon dioxide which will probably not occur after operating conditions have been improved.

The chart in Fig. 8 covers the record of a single heat in a hand fired melting furnace. Flue gas samples were taken from the throat of the furnace. This chart probably represents average hand firing conditions although it is possible to obtain higher carbon dioxide by the use of additional air through the wind bung.

The chart in Fig. 9 is the record of 26-ton heat melted with powdered coal. This curve represents the average performance and the melting ratio on this heat was 3.4 or 454 pounds of coal per ton of iron melted. Had this curve been a straight line at 18 or 19 per cent less coal would have been used. The influence of gases given off from the bath do not become noticeable until the latter part of the heat. At present the firing schedule calls for a slightly reducing flame running 17 per cent carbon dioxide until the charge is melted after which the flame is changed to a slightly oxidizing condition giving flue gas with 18 per cent carbon dioxide. Scheduling the operation of a furnace within such close specifications may seem rather ambitious but results so far have been rather encouraging in this direction.

The straight line charts bring out the fluctuations in

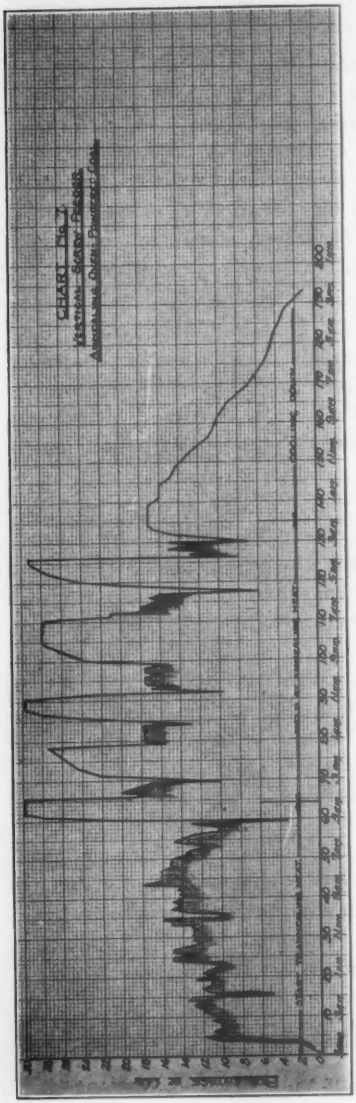


FIG. 7

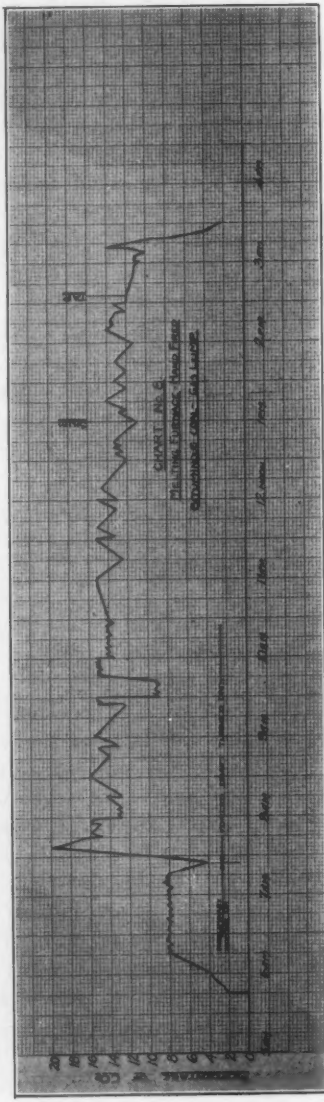


FIG. 8

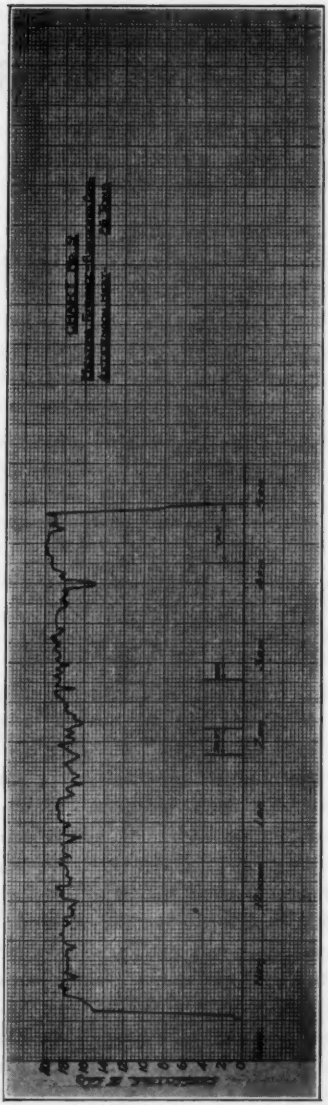


FIG. 9

analyses more clearly than circular charts but the furnace operator after some experience can read the latter with the same degree of accuracy.

Discussion—Use of Carbon Dioxide Recorders Controlling Combustion of Powdered Coal

D. M. Scott.—Certain charts which we have been able to get of the action of carbon dioxide have proved very interesting. There later will be a paper on powdered coal, but the present paper ties in with powdered coal, because, in the burning of this fuel, while good ratios are obtained under ideal conditions, it is very easy to get poor ratios and waste a considerable amount of fuel. All of our annealing ovens are operated with powdered coal, also the melting furnaces, and we have carbon dioxide recorders on all our annealing ovens and all our melting furnaces, and we have found that where we get a good mixture of coal and air, our ratios come up somewhere around the claimed ratios of the powdered coal people, so we are quite enthusiastic, believing that we are going to get ultimately an average ratio which can be gotten under ideal conditions through the use of this carbon dioxide recorder. Briefly the carbon dioxide recorder is an instrument which takes a sample of the flue gas and reduces it to a constant temperature and a constant pressure, and then the carbon dioxide is absorbed and the percentage of carbon dioxide is registered on a chart. These samples are continuous, and we get a sample about every two and a half or three minutes. Now all malleable people are of course interested in powdered coal, because the installations have been very successful. We have found this in our melting furnaces, that in the hand fired furnace our percentage of carbon dioxide is usually around 12 per cent or 14 per cent, whereas we can get, in a powdered coal furnace around the theoretical maximum, which means ideal combustion. It is principally for that reason that powdered coal has shown a higher thermal efficiency. The reactions are very simple. If you have excess air or excess coal, you will have, in your flue gases the free oxygen or carbon

dioxide, both of which represent a thermal waste, and there is no way without a flue gas analysis, except by the eye, which is very uncertain, of judging when you will get the correct proportion of air and coal. Carbon dioxide recorders have not been used very extensively, and before we put them in we wrote to a great many people and almost invariably the reply was that they did not believe in them; they had had them and tried them and they were not any good. I have just two messages. One of them is that we have for a year successfully used carbon dioxide recorders and they are not giving us any more trouble, at least not much more than our recording pyrometers, and we do know, by actual measurement, that we are getting an increase of thermal efficiency in our ovens and also in our furnaces. If foundrymen can get complete combustion, they certainly are getting ideal conditions and we have actually gotten them and expect to get them more consistently than we have now. The use of carbon dioxide recorders on industrial furnaces is not very general, and for that reason I think it is rather a new topic for the Foundrymen's Association.

E. E. GRIEST.—What carbon dioxide do you maintain?

D. M. SCOTT.—The theoretical maximum carbon dioxide for Pittsburgh coal is supposed to be about 18 2/3 per cent. We have gotten around 19 per cent, which means that we were getting actually just exactly the right amount of air with exactly the right amount of coal.

E. E. GRIEST.—What will you run on an average, that is as an average condition?

D. M. SCOTT.—It depends very much on what kind of a feeder you have; some feeders are very erratic; we have one or two feeders that give us almost a constant 18 per cent. Of course those annealing ovens use the smallest amount of coal.

E. E. GRIEST.—How about your melting furnace?

D. M. SCOTT.—We have not been so successful, because it is difficult to take samples and get the sample tubes to stand up under the scouring action of the flame and also the high temperatures. The tubes were inside the melting furnace, about

six feet from the burner. We have in this paper one chart of a melting furnace heat that ran quite constantly around 18 per cent, and then toward the end of the heat the increases due to slag reactions, carbon dioxide increases, took place.

J. M. KITTLE.—On the same subject, it might be of interest to tell of an experiment with oil. We found, with this same instrument Mr. Scott is talking about, about 16 per cent, but we found we had to use that instrument at about three places on the furnace. We were surprised at the difference in the different readings in about four feet of space. We found that was the hardest thing to control; while you might get up to 16 or 17 in one place, three feet from the front bridge wall, you would have to watch it very carefully to keep that same per cent on the bulk of it, and we had to apply recorders at about three different places.

D. M. SCOTT.—We had one furnace at one time with two sampling tubes, one about the middle of the furnace and one about six feet from the burners, and we got practically no difference in the flue gas analysis. With powdered coal the combustion seems to be complete very close to the burners, and does not seem to be changed as it crosses the bath. There is no opportunity to form carbon monoxide.

Use of Pulverized Coal in Malleable Foundries.

By E. E. Griest, Chicago, Illinois

The historical record of the use of pulverized coal in general practice and in foundries, in particular, has been outlined in other papers presented to this association and it seems unnecessary to again mention its early history and growth. During the past three years the use of pulverized coal for all malleable foundry operations has been given much thought by combustion, foundry and metallurgical engineers. This together with the interested and intelligent co-operation of foundry executives, has changed the status of pulverized coal from the experimental to the practical operating stage. At the Philadelphia meeting of the A. F. A. in 1919, several papers on pulverized coal were presented. On the subject of air furnace practice, however, it was observed that the art was in the experimental stage, but progress had been made. Harrington in his "Powdered Coal as a Fuel" published July, 1920 says (P. 210), "In this class of work (the melting of iron and steel for castings in malleable and steel foundries), powdered coal has not to date made any great strides. The reason for this is not known. However, in the next two years there is no doubt that powdered coal firing on these furnaces will be as general as on annealing work." This prophecy has been realized. There are now at least ten foundries using pulverized coal for melting and from the interest expressed many more are giving the subject serious consideration.

Just why pulverized coal has not been used in air furnaces when it has been used so successfully for annealing, is difficult to explain. There was, apparently, a prejudice against the use of any kind of fuel except lump coal. Conservatism probably explains this attitude. When good malleable is being produced at a reasonable cost, radical changes in methods are not looked upon with favor. In reality pulverized coal methods

for firing a melting furnace are not so radically different from hand firing methods as first thought would indicate. If the same quality of coal is used the only difference between the two methods is the preparation, which in this instance means the size of coal used. Sufficient air to support combustion is necessary in both methods.

The Chicago Railway Equipment Co. owns two malleable foundries, one at Marion, Indiana and the other at Grand Rapids, Mich. Prior to installation of pulverized coal equipment the best quality of lump coal from the Eastern Kentucky or West Virginia fields was considered the most economical coal to use for melting furnace operation. While coal from other fields was used from time to time, yet Kentucky coal was considered to be the most satisfactory. Of late years, up to 1921, this coal was in good demand and while it could be purchased at a fairly low price at the mines, yet the high freight rate made it rather high priced when delivered at the foundries. Lump coal during periods of greatest demand for coal commands a relatively high price and during periods of railroad congestion, bad weather, etc. the continuity of delivery is anything but satisfactory.

As both foundries are located close to the Indiana coal fields, it was thought that a saving of no small amount could be expected if Indiana coal could be successfully used for melting. If coal of any preparation could be used, the source of supply could be so arranged as to insure continuous operation under almost any condition. If coal from various fields and of any preparation could be used and in addition a lesser amount consumed with a decreased foundry labor cost, our management was willing to consider the expenditure necessary to provide equipment for the accomplishment of this purpose. Figures submitted indicated that the investment, while of no small amount, would be justified by the savings contemplated. While the general arrangement of foundry buildings is very different at the two plants, yet the general arrangement of the pulverized coal systems is much the same. The pulverized coal buildings and equipment therein are practically alike at both plants. In describing the plants, one description will answer

for both except when especially noted otherwise. (A fairly complete description of our Marion plant is given in the issue of *The Foundry* of December 15, 1921).

Storing and Handling Coal

It has been the practice of this company for many years to keep a fair amount of coal in storage. The pulverized coal buildings were located so as to be as near the coal storage space as conditions permitted. At Marion, the building is located about central of space in which about 3000 tons of coal can be stored. At Grand Rapids, where more ground space was available, the building is about central of a space in which about 6000 tons of coal can be stored and about half of this can be transferred from storage to the track hopper by the swinging of the boom of the locomotive crane. Fig. 1 shows pulverized coal plant, with pulverized coal distributing lines running to furnaces and annealing ovens.

An ideal arrangement for handling coal in such a plant would be to have all coal delivered in hopper bottom cars with such regularity that the supply would be plentiful, yet no coal would have to be stored. With a plant in close proximity to coal mines, the storage for crushed and pulverized coal could be so arranged as to avoid any manual coal handling cost. The next best arrangement is to arrange the plant so that storage coal can be handled into the track hopper with a minimum expense. Our track hopper has a capacity of 50 to 60 tons; the crushed coal storage bin 60 tons and the two pulverized coal bins 50 tons. On the basis of operating at capacity, our plants have storage space for crushed and pulverized coal for three days operation.

From the track hopper, coal of any preparation feeds by gravity through a reciprocating feeder into a coal crusher. The lumps are crushed so that the coal leaves the crusher in about the size that would pass through a 1¼-inch screen. From the crusher the coal drops into a bucket conveyor, which conveys it to a 60-ton bunker located near the top of the building. During this time much of the free moisture drains from the coal. The bunker can be of any size. It should be

sufficiently large to store an amount of coal that will keep the plant in operation should any trouble occur with the crusher or conveyor. It is advisable to keep the bunker well filled.

From the bunker coal feeds on a belt which conveys the coal under a magnetic separator, for the removal of spikes, picks, etc., into an automatic weighing scale. From this scale the coal drops into a screw conveyor which takes it into one end of a cylindrical dryer. As the dryer revolves slowly, hot gases from a hand fired combustion chamber pass through the moving coal and remove most of the combined moisture as well as the free moisture. When the coal reaches the lower end of the dryer it falls into another screw conveyor which delivers the coal to a bin located adjacent to a pulverizer. From this bin the coal is fed automatically, but under control of the attendant, into a pulverizer of the air separator type. As the coal is crushed to the desired fineness, it is lifted by a suction fan into a collector, the air returning to the pulverizer to be used again and the coal dropping into one of two 25-ton pulverized coal bins. These bins located in the pulverized coal building are the only ones in which pulverized coal is stored.

Controlling Air and Coal Mixtures

From the storage bins the coal is fed by screw conveyors into the suction side of a blower fan (as required at the furnaces). At this point in the system an automatic float valve is installed that changes its position as valves at furnaces or ovens are opened or closed. The arrangement is such that a constant mixture of coal and air can be maintained. The size of distributing pipes are so calculated that the coal remains in suspension in the air even when no coal is being used. This proportion is usually maintained at from 35 to 50 cubic feet of air per pound of coal. In this proportion the mixture is *not* explosive, but requires the addition of at least 100 cubic feet of air for combustion, which is injected into the mixture at the furnace, and which is supplied by a motor or turbine driven fan located near the melting furnace.

As a valve in the coal line (mixture of 35 to 50 cubic feet of air per pound of coal) at a furnace is opened, an increased

amount of air enters the distributing system instantly and thus the pressure in the distributing lines is maintained constant. At the same time by a synchronous control a variable speed motor connected to the feed screws from the pulverized coal storage bins is speeded up sufficiently to feed an increased amount of coal into the line so that the proportion above referred to is maintained. The proportion of coal and air can be easily adjusted, but when set automatically maintains the correct proportion.

From this description it might be thought that the arrangement is complicated and pregnant with trouble, but as a matter of fact the apparatus is simple, has few parts and has given no trouble whatever.

When in operation, the distributing line is always full of the mixture of coal and air and remains filled at all times regardless of the number of furnaces operating. The distributing line is returned to the pulverized coal building where the coal that is not used at the furnaces is separated from the air by means of a collector, the coal returning to the storage bin and the air to the distributing line. After all furnaces have been shut off, the blowers are operated for a short time without feeding additional coal into the line and in this way all pulverized coal is returned to the storage bins in the pulverized coal building, thus there is no storage of pulverized coal near the ovens or furnaces or in the foundry buildings, and all motors and machinery are in one building.

Standardization of Equipment

The pulverizing of coal and the handling of the coal incident thereto has been practiced for so many years that standard practices have been established. There are numerous companies manufacturing equipment of this kind and the equipment has been developed to a high state of efficiency. To one unfamiliar with the practice there appears to be a great deal of machinery. But blowers, conveyors, crushers and pulverizers give little trouble even when given very mediocre attention. The balls or rollers and races of pulverizers must be renewed occasionally, but provision has been made

FIG. 1—VIEW OF PULVERIZED COAL BUILDING AT GRAND RAPIDS PLANT SHOWING DISTRIBUTING AND RETURNING LINES

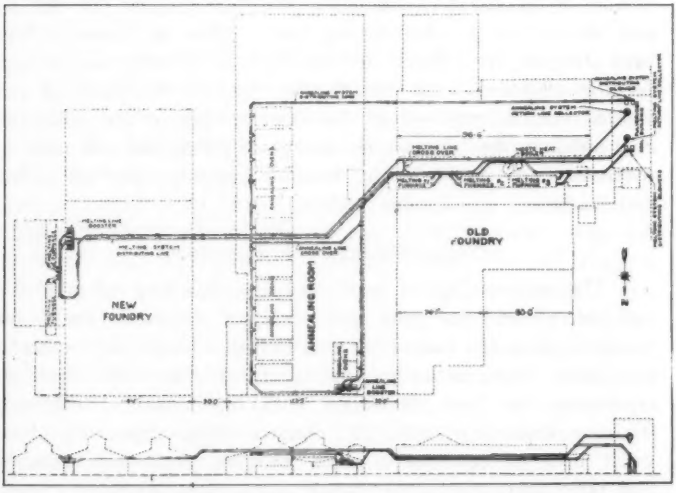


FIG. 2—ARRANGEMENT OF MELTING AND ANNEALING EQUIPMENT IN THE MARION PLANT OF THE CHICAGO RAILWAY EQUIPMENT CO. SHOWING PULVERIZED COAL LINES

for the quick renewal of such parts, so that little delay results when these parts require renewal.

When distributing lines are long, booster sets may be installed in order to maintain sufficient velocity of the mixture. These booster sets are merely motor driven fans which may operate continuously with no more attention than any other motor or fan. In recent installations the boosters have been eliminated. Where the lines are of sufficient length as to require boosters, substations are provided. The coal is delivered by a high pressure air ejector delivery system to the substation, and the coal is delivered to the furnaces through a relatively small distributing system. Where some furnaces are isolated, this system could be operated for somewhat less expense than could a system which requires boosters.

The arrangement of the melting furnaces at our Marion foundry is shown in Fig. 2. When the melting furnaces in the new foundry are being operated, it is necessary to operate the booster blowers which are located as indicated. When melting furnaces numbers 2 and 3 only are being operated, a cross-over connection is made at the point indicated and in this way the length of distributing line is greatly shortened and, of course, the booster is not required. A cross over installed in the annealing system permits the operation of six annealing ovens and eliminates the necessity for the booster.

Power Consumption

The power consumption of the motors used for preparing and distributing pulverized coal was obtained with the aid of a graphic wattmeter, which was placed in the circuit of the motor under test and a check was made with an integrating watt hour meter placed in the motor circuit at the same time. Tests were conducted for a sufficient length of time to record actual operating conditions.

From these data a summary is given below showing power consumed to prepare 2000 pounds of Eastern Kentucky coal of nut, pea and slack preparation of the following analysis:

	Per cent		Per cent
Moisture	2.53	Sulphur	.55
Volatile	31.56	B.t.u. as received	12373
Fixed carbon	53.79	B.t.u. dry	12694
Ash	12.12	B.t.u. Combustible	14694

Power consumed per 2000 pounds of coal.

Operation	Horsepower of Motor	Kilowatt-hours per ton of coal
Reciprocating feeder	5.0	.073
Crusher	15.0	.212
Bucket conveyor to storage bin	10.0	.191
Belt and screw conveyors—Storage bin to dryer	5.0	1.150
Magnet	—	.475
Dryer	7.5	1.008
Screw conveyor—Dryer to pulverizer bin	3.0	.619
Pulverizer—1¼ ton	25.0	17.800
Exhauster Fan—Pulverizer to storage	7.5	2.112
Total		23.64

From these figures it would appear that some of the motors are quite large for the load carried, but it should be considered that the starting load is quite high. Most of the machinery is heavy and slow moving. The instantaneous starting load is high, but after it is started the power required to keep it moving is relatively low.

With a 5-ton per hour capacity pulverizer, the power consumption per ton of coal is greatly decreased and tests conducted show that 1 ton of Eastern Kentucky coal is pulverized with a current consumption of 13.20 kilowatt-hours.

Power required to distribute one ton of coal in the melting furnace line:

Operation	Horsepower of Motor	Kilowatt-hours per ton of coal
Feed screws	3.0	2.11
Distributing blower	40.0	27.1
Total		29.21

Power required to distribute one ton of coal in the annealing oven line:

Operation	Horsepower of Motor	Kilowatt-hours per ton of coal
Feed screw	3.0	2.11
Distributing blower	40.0	30.00
Total		32.11

If the lines are of sufficient length to require boosters, the power consumption will be increased by an amount approximating the power required to drive the distributing blowers.

Secondary air is required for both melting furnaces and annealing ovens in amounts varying with the number of furnaces or ovens being fired at one time. The secondary air used in hand fired furnace practice is sufficient, generally for pulverized coal operation. For annealing ovens the secondary air is supplied by a motor driven fan. The power required to supply this air for varying numbers of ovens of 35 tons capacity is as follows: For two, the average load is 3.6 kilowatts; for three ovens fired at one time it is 4.0 kilowatts; for four ovens it is 4.5 kilowatts; and for five, the load is 5.0 kilowatts.

Summary of Power Consumed

One ton (2000 pounds) of Eastern Kentucky coal prepared and distributed to melting furnaces and annealing ovens requires expenditure of electrical energy as follows:

Melting furnace	Kilowatt hours
Crush-pulverize, etc. (1¼ ton pulverizer)	23.64
Feed screws	2.11
Distribution (No booster)	27.10
	52.85
If booster required add	26.49
Total	79.34
If pulverized in 5-ton pulverizer, subtract	4.60
	74.74

Annealing ovens	Kilowatt hours
Crush-pulverize, etc. (1¼ ton pulverizer)	23.64
Feed screws	2.11
Distribution (No booster)	30.00
Secondary air	4.50
	60.25
If booster required, add	30.00
Total	90.25
If coal pulverized in 5-ton pulverizer, subtract	4.60
	85.65

Knowing the cost for current, the power cost is easily figured. These figures cover power only and are outlined in

this detail as authentic figures of this kind were not available at the time our plants were purchased. The power figures given above were obtained under extremely unfavorable operating conditions, that is, the plant was operating at about 20 per cent capacity. Under normal operating condition with large heats and large tonnages being annealed, the power costs would of course, be very different from these outlined above. With a system such as ours, we have a maximum of flexibility, but the maximum efficiency, of course, is not obtained under minimum production conditions. Unfortunately, our foundries have not operated under normal production conditions since the installation of the pulverized coal plants. As soon as conditions permit, a further test will be made to determine the power consumption under normal operation conditions. The figures given above while somewhat misleading, should not be considered as being applicable under favorable operating conditions. The figures for pulverizing, elevating, crushing and delivering the pulverized coal to the storage bins may be considered as representative, regardless of the production in the plant.

Coal Suitable for Burning in Pulverized Form

It would seem from tests conducted that almost any kind and quality of coal can be successfully burned. Some coals cannot be burned in this form economically, although it might be possible to mix certain inferior coals with good quality coal and get fair results. The ideal coal to use would be low in ash and moisture and high in volatile and heat units. Many coals from the Eastern Kentucky and West Virginia fields meet these specifications.

As pulverized coal is ground into very small particles it would seem that coal purchased as slack would be the most economical. The statement has been frequently made that slack preparation, or nut pea and slack, as is commonly produced in the Kentucky and West Virginia field, requires no preliminary crushing. It is true that such coal can be fed directly into pulverizers, but more power is required to pulverize large lumps of coal than is required to pulverize small lumps. The coal should be run through a crusher to break up the larger pieces as these large pieces reduce the capacity of the pul-

Table I

Coal fired	Kind	Moisture, per cent	Volatile, per cent	Ash, per cent	Sulphur, per cent	Fixed carbon, per cent	As received	B.t.u. dry	Combustible
Ky. No. 1	N. & S.	2.53	31.56	12.12	0.55	53.79	12,373	12,694	14,694
Ky. No. 2	R. M. R.	2.37	34.09	6.18	0.41	57.36	13,589	13,913	14,859
Ky. No. 3	N. P. S.	3.21	35.33	8.15	0.72	53.31	12,700	13,121	14,328
Ky. No. 4	N. & S.	3.46	31.08	13.36	0.90	52.10	11,633	12,046	13,986
Ind. No. 1	M. R.	7.50	35.69	11.31	1.26	45.50	11,265	12,166	13,675
Ind. No. 2	M. R.	8.02	34.93	9.07	1.03	47.98	11,119	12,088	13,411
W. Va. No. 1	N. & S.	6.37	31.98	11.86	0.73	49.79	....	....	....
Ky. No. 5	N. & S.	5.19	29.46	20.23	1.36	45.12	10,199	10,757	13,675
Ind. No. 3	Screen.	12.34	30.93	14.52	1.58	42.21	10,258	11,633	14,025
Anth. No. 1	Culm.	4.94	8.91	24.92	....	61.23	10,289	10,814	14,699
Ky. No. 6	N. & S.	1.66	34.97	9.80	1.12	53.57	13,069	13,289	14,940

NOTE:—N. & S.—Nut and slack.
R. M. R.—Resultant mine run.
N. P. S.—Nut, pea and slack.
M. R.—Mine run.

verizer and materially increases the cost. As has been previously noted the power required for crushing is comparatively little. Unless the slack is entirely free from lumps no larger than a 1-inch cube, it should be run through a crusher. It is less costly to crush coal in a crusher than in a pulverizer.

Coal as received should be analyzed occasionally to check the shippers' methods of mining and preparation. This is particularly advisable if mine run or slack is used since all cuttings from roof and floor are finally deposited in the finest preparations. From the same mine, lump coal may show an ash content of 3 per cent, mine run 6 per cent and slack 10 to 12 per cent and the heat units of corresponding variations. For this reason lump coal is worth more than mine run coal and the latter is worth more than the slack, all, of course, from the same mine. The cost of crushing can be almost ignored. Some trouble may be experienced with very large lumps clogging the crusher. The resultant coal from a 4-inch screen makes a very fine preparation.

From data gathered covering cost of pulverizing, etc.; together with a study of the results obtained from various kinds of coal and considering also the analysis of the coal the price that any coal is worth can readily be calculated. Do not expect to get the same coal to iron ratio from slack or mine run preparation as you would obtain from lump coal from the same mine. The ratio will decrease in about the same relative proportion as does the heat unit content or as the ash content increases.

Analysis of some coals burned successfully in melting and annealing furnaces are shown in Table I. While all of these coals were successfully burned, yet there was a large difference in the cost per ton of iron melted or annealed. Kentucky No. 2 gave the best iron to coal ratio, but it was not worth the high price wanted for it. Kentucky No. 3, considering price and performance was the most economical.

Some tests were made with anthracite culm as a matter of information. When it was first tried in a melting furnace much trouble was experienced in getting a flame. The coal was of very poor quality as is indicated by the analysis below:

	Per Cent
Moisture	4.94
Volatile	8.91
Fixed Carbon	61.23
Ash	24.92
B.t.u. per pound as received	10289
B.t.u. per pound dry	10814
B.t.u. per pound combustible	14699

The trial, when it was burned in the same manner as bituminous coal, was a failure. It was mixed with bituminous coal and little better results were obtained. Finally the furnace was heated with bituminous coal and then anthracite was turned in and it was found that heats could be taken off in this manner. Almost any bituminous coal, sufficiently low in sulphur, would be more economical than this quality of anthracite at the same cost per ton. While only a small quantity of this coal was used, yet we found it to be more expensive to pulverize and much more destructive on the equipment due to its abrasive constituents.

Moisture in Coal

Some authorities contend that moisture up to eight or ten per cent is not particularly objectionable and that it is unnecessary to dry coal containing this amount of moisture or less. Some companies have considered installing pulverizing equipment without dryers in order to keep down the cost of the plant. If a plant was assured of a supply of coal of a low moisture content such as is represented by Kentucky No. 2 or No. 6, there would be some reason to consider a plant with-

out a dryer. If Indiana, Illinois or any of the western coals are used even occasionally a dryer is necessary for economical operation. Our experience has been that coal should be dried so as to contain not more than 1½ per cent moisture (preferably less than 1 per cent) if best fuel economy is to be obtained from melting furnaces. While it is feasible to burn coal with 10 per cent moisture it is certainly not economical to melt iron with such coal. In ordinary heating furnaces, in boiler combustion chambers and in annealing ovens, the moisture content does not seem to be so important, but for quick heats, a minimum of oxidation and a high coal ratio in melting furnaces, real dry coal is essential. For plants located in proximity to the central west and western coal fields, the dryer capacity should be carefully considered and one of much greater capacity should be used than where eastern coals are available. To dry Kentucky coals to about 1 per cent moisture require 1.3 per cent of the total coal dried and for Indiana coal running about 7½ per cent moisture there is required 1.8 per cent of the coal dried. Free moisture from rain and snow gives very little trouble as most of it drains off before the coal reaches the dryer. The combined or inherent moisture, which is the moisture shown in analyses, can only be reduced or eliminated by the action of heat. If wet coal is fed into a furnace, heat is required to vaporize the moisture in the form of wet coal and heat that could be used for melting must be used for evaporating the water. In a melting furnace, for example, the object is to melt iron quickly and economically. The evaporation of water in such a furnace retards the melting operation. The drying of coal can best be accomplished in the dryer designed especially for the purpose.

Dry coal is more easily pulverized than is wet coal and the cost is correspondingly less. Wet coal packs quickly and has a tendency to pack and clog in any receptacles or mechanisms it passes through or is stored in. It is more susceptible to sponetaneous combustion because of its tendency to pack.

Fineness of Pulverizing Important

The finer coal is pulverized the more efficiently and satisfactorily it can be burned. Here again, some authorities con-

tend that accepted practice is wrong. Again it can be said that relatively coarse coal can be burned successfully, but not nearly so economically as very fine coal. For metallurgical furnaces, the standard most commonly accepted, viz., 95 per cent through a 100 mesh screen and 85 per cent through a 200 mesh screen, has proven satisfactory. Coal ground to this fineness is mostly an impalpable powder.

The object of grinding coal fine is to have the coal so prepared, with sufficient surface exposure, that instantaneous and complete combustion may be expected. If a lump of coal say 3 inches cube is fired into a combustion chamber, there is exposed 54 square inches of area to the action of heat. There is only required for combustion of these exposed surfaces a relatively small amount of air. It is known that this lump of coal will break up into many small pieces after it has been subjected to heat for a short time and when that occurs the surface exposed is many times increased. A much larger amount of air is then required to permit of burning of these many small pieces. A stoker may not think of this in the manner above outlined, yet a good stoker will endeavor to supply the correct amount of air by keeping the grates clean and by firing the coal in small quantities. Under the best of conditions and with the most highly skilled stokers there will be an excess of air one moment and a deficiency the next, but usually there is a large excess.

With coal finely ground in accordance with established practice, it is fair to assume that the average size piece will be less than 1/600 of an inch cube. Assuming this, then a lump of coal of the size of a 3-inch cube will be, when pulverized, divided into six billion pieces. These six billion pieces have an area of 688 square feet whereas the 3-inch lump had an area of only 54 square inches. Is it not fair to assume that with this greatly increased surface exposed a much quicker burning action will result?

It is well to remember also that all of the coal fed into the furnace is of approximately the same size. With hand firing each shovel full will contain many different sizes, yet before this coal can be completely consumed it must be broken down (by

the action of heat or otherwise) into very minute particles. Time is required to permit this breaking down process and at the same time a large amount of excess air is entering the furnace in anticipation of the time when it will be required to assist in the combustion of the many small pieces. The stoker may assist the action of the heat in breaking down the lumps by poking and raking. All he can do is to assist in exposing more unburned surface for combustion. The fire tools of the stoker are not as efficient for this work as is a pulverizer. Pulverized coal when dry and finely ground is highly combustible when mixed with the proper amount of air. Theoretically, about 140 cubic feet of air are required for complete combustion of one pound of coal. It has been found from experience that about 175 cubic feet of air per pound of coal is the proportion best suited for general purposes. There may be times when more air is wanted during a portion of the time in order to produce a decided cutting action. Again a lesser amount may be wanted if a neutral flame is necessary. With a properly designed equipment, almost any reasonable air ratio can be instantly obtained and maintained for any period.

Pulverized Coal Aids Quick Melting

In a malleable melting furnace, it is desired to heat the charge quickly and get the metal out in the shortest possible time. Pulverized coal approaches an ideal fuel to meet this requirement. To get maximum results, however, it is essential that combustion take place as near to the end of the burner as possible so that the heat can be utilized for the full length of the furnace. Therefore, as the coal enters the furnace there should be a sufficient amount of air so that each particle of coal will be surrounded by an amount of air that will permit perfect and complete combustion, but there should not be sufficient excess air to cause dilution of heat. This means for an ideal condition, a perfect mixture of coal and air.

The particles making up finely pulverized coal are more nearly uniform in size, than are the particles making up ordinary hand or stoker fired coal. If coal is ground so that 95 per cent will pass through a 100 mesh screen then about 60 per cent of it will pass through a 300 mesh screen. In such

a material then are a few particles larger than a 1/200 inch cube and many very much smaller than a 1/600 inch cube. For each different sized particle a different amount of air would be required for combustion of that piece. It is unreasonable to expect any appliance or apparatus to accomplish the practically impossible feat of surrounding each of the millions of particles with the correct amount of air for perfect combustion. Recognizing these facts, it is unreasonable to expect to melt iron quickly with coal without an excess amount of air, and this means a certain amount of oxidation loss. Keep this loss to a minimum by the use of a minimum amount of excess air, all of which should be admitted with the coal. Abandon the top blast when burning pulverized coal. With many hand fired furnaces, top blast is necessary to deflect the gases to the charge and to protect the bungs. In doing this it cools the gases, but furnishes air also to complete combustion. It may be classed as a necessary evil. With a properly designed pulverized coal furnace, the flame is direct on the charge and no air other than that which enters the furnace with the coal is required to complete combustion.

Methods of Introducing Coal into Furnace Compared

There are two general methods for introducing coal into a furnace. There are many modifications of these two general methods. One method may be designated as the "bin system," in which pulverized coal is stored in a bin at each furnace. The coal is transferred from the pulverizer building by a screw conveyor or by compressed air, the latter being most generally used in late installations. From the storage bin the coal is withdrawn by the movement of a feed screw which is usually operated by a small variable speed motor. The feed screw delivers the coal into a chamber of special design into which blast air (it may be compressed air, although fan blast air is generally used) is also admitted. The air and coal are mixed in this or additional chambers and the mixture then fed into the furnace. Some of these mixers or burners (or carburetors as they are sometimes erroneously called) are quite complicated in design. The problem of thoroughly and completely mixing the coal and air in the correct proportions, however, must be

solved if a maximum efficiency and economy is to be obtained. With the storage bin located at the furnace, this mixing operation must be accomplished in a limited space, else valuable shop space will be occupied.

The system installed in our foundries is known as the "circulating system." As previously explained, the coal is fed into a pipe through which a current of air is passing and this mixture induced through a distributing blower. While passing through the blower, the coal is unquestionably thrown to the outer periphery of the fan blades by centrifugal action, but as it is forced through the outlet pipe, it mixes with the air and is then carried in suspension to the furnaces. In this stage the mixture is in the proportion of one pound of coal to say, 35 cubic feet of air. The proportion may be changed to suit the particular furnaces or number of furnaces being operated. This amount of air is not sufficient to support combustion. There is a mixture of coal and air circulating throughout the system. To make this mixture burn, however, there must be added a large volume of air. This is added into the burner at the furnace. In other words, the rich mixture is simply diluted by the addition of fan blast air just prior to the entrance of the mixture into the furnace. The coal and air are already intimately mixed, else the coal would not be carried in suspension. To further substantiate this statement, it may be of interest to know that the outlet for a furnace may be taken from the top, bottom or side of a distributing pipe. The air used for distributing the coal is also used for combustion so that less additional air is required at the furnace than is necessary for bin system equipment.

Some engineers claim to have perfected devices for automatically controlling the proper volume of air to correspond with the coal consumed. These devices operate on the principle that a certain kind of coal requires a definite amount of air for good combustion. This relation is determined by trial after which the coal and air control are so connected that when an increased amount of coal is used a corresponding increased amount of air is automatically admitted. When a change of coal is made this device must be reset. It is assumed that for each

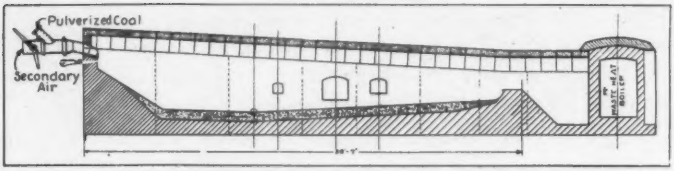


FIG. 3—LINE DRAWING SHOWING GENERAL CONTOUR OF A MELTING FURNACE

cubic inch (or any unit of volume) of coal a certain volume of air is required. The unit of volume is not proper for measuring the heating value of coal. If the air were governed by the B.t.u. or volatile and fixed carbon content of the coal, it would come more nearly meeting requirements. A control apparatus that would automatically increase or decrease coal or air as required to maintain furnace temperature and complete combustion, would insure maximum efficiency. It is hoped that some enterprising engineer will work out such a control.

It seems unnecessary to rebuild hand fired melting furnaces to properly burn pulverized coal, but some alterations must be made in the fire box of the furnace. The burners may be

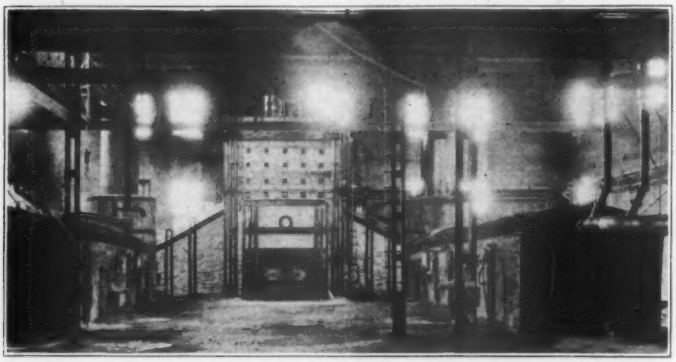


FIG. 4—TWO 25-TON MELTING FURNACES WITH WASTE HEAT BOILER IN THE BACKGROUND. THE BOILER CAN BE FIRED WITH WASTE HEAT GASES FROM ONE OR BOTH MELTING FURNACES OR WITH PULVERIZED COAL DIRECT. IT ALSO IS ARRANGED FOR HAND FIRING

placed in the end of the furnace; the ash pit filled up; the bridge wall removed and the furnace bottom extended as far as possible. It may be necessary to increase the height of the back end of the furnace, but this will depend on the height of the fire box of the hand fired furnace. It may also be necessary to change the height of the bridge wall which is located in the neck of the furnace. The capacity of a furnace is generally increased from 10 per cent to 20 per cent. A typical melting furnace is shown in Fig. 3.

The time required for taking off heats varies with the kind and size of charge. The quality of coal has some bearing on this, but generally the volume of coal fired can be increased without affecting the melting time. The time for taking off heats of the same size and same general charge is remarkably consistent. It is not unusual to run for a week with a total variation in time of less than 15 minutes. During one week this variation was only 5 minutes. With records and experience from 800 heats, the figures are representative and

Table II

Heat No.	Tons melted	Per cent pig iron in charge	Melting time in hours	Firing time in hours	Furnace hot or cold	Tons melted per hour
1	18.0	35.0	5.25	5.90	Cold	3.44
2	19.0	34.2	5.60	6.50	Hot	3.39
3	20.0	35.0	5.00	6.00	Cold	4.00
4	19.0	35.0	4.50	5.25	Hot	4.22
5	21.0	33.3	5.25	5.83	Cold	4.00
6	18.0	35.0	4.50	5.50	Hot	4.00
7	20.0	35.0	4.80	5.81	Cold	4.17
8	21.0	40.0	5.25	6.00	Cold	4.00
9	19.0	35.0	4.75	5.75	Hot	4.00
10	21.0	40.0	5.33	6.16	Cold	3.94
11	20.0	35.0	5.40	6.30	Hot	3.70
12	23.0	40.0	5.60	6.26	Cold	4.10
13	12.0	40.0	4.50	5.08	Cold	2.67
14	12.0	35.0	4.00	4.50	Hot	3.00
15	12.4	38.7	4.10	4.60	Cold	3.00
16	13.0	35.0	4.08	4.66	Hot	3.18

authentic. In Table II is listed consecutive heats from one furnace which may be considered representative.

On this particular run the heats varied from 12 tons to 23 tons. Some inconsistencies appear, but it must be considered that with such variations in the charges it would be unreasonable to expect the same uniform performance as would be gotten when the charges were of uniform size. During another run of 12 heats varying from 14 to 19 tons, the heats from the

hot furnaces were melted in from 4 to 4.33 hours and in the cold furnace from 4.25 to 4.92 hours. The furnace man reports to the foundry at from 4 a. m. to 6 p. m. depending on the size of heat; starts a motor; holds an oil soaked rag in front of the burner; opens the coal and air valves and the day's work is started. By 9 or 9:30 a. m. the metal is ready to pour. The pouring time is governed by the number of molders and the class of work, but generally by 10 or 10:30 a.m. the metal is out, the coal is shut off and recharging of the furnace begins. By 11 or 12 the burners are again lighted and by 4 p. m. pouring again starts.

An example of good every day practice at our Marion foundry is given below:

	Heat No. 533	Heat No. 534
Charge—Total	44,000	44,000
Fire lighted	5:00 a. m.	12:00 Noon
First skim	8:15 a. m.	2:45 p. m.
Second skim	9:40 a. m.	3:30 p. m.
Ready to pour	10:20 a. m.	4:20 p. m.
Metal out	11:15 a. m.	5:15 p. m.
Melting time	5.35 hours	4.33 hours
Firing time	6.25 hours	5.25 hours
Iron melted per hour	4.13 tons	5.08 tons
Iron melted per hour (Total firing time)	3.52 tons	4.19 tons

Heat No. 533 melted in a green furnace.
Heat No. 534 melted in a hot furnace.

The total melting time for the two heats was 9:66 hours and total firing time 11:50 hours. The silicon was charged at 1:25. Hard iron analysis from heat No. 533 was carbon 2.40, sulphur 0.085, silicon 0.94, manganese 0.30, phosphorus 0.129.

As an example of short time for taking off small heats in a 25-ton melting furnace, the record below from our Grand Rapids foundry may be of interest:

	Heat A	Heat B
Charge	24 000	20.000
Furnace	Cold	Hot
Fire lighted	8:00 a. m.	12:50 p. m.
First skim	10:13 a. m.	2:30 p. m.
Ready to pour	11:30 a. m.	3:12 p. m.
Metal out	12:20 p. m.	3:56 p. m.
Melting time	3 5 hours	2.36 hours
Total time	4.33 hours	3.10 hours
Iron melted per hour	3.43 tons	4.23 tons
Iron melted per hour (Total firing time)	2.77 tons	3.22 tons

From the time fire was lighted for first heat until completion of pouring of second heat, the total elapsed time was 7 hours 56 minutes. No trouble is experienced in the operation of the furnaces. The furnace man has plenty of time to lute the bungs. At the beginning he keeps close watch of the flame and adjusts the coal and air valves as frequently as is necessary for good flame condition. After the men have become familiar with the operation of a furnace with pulverized coal

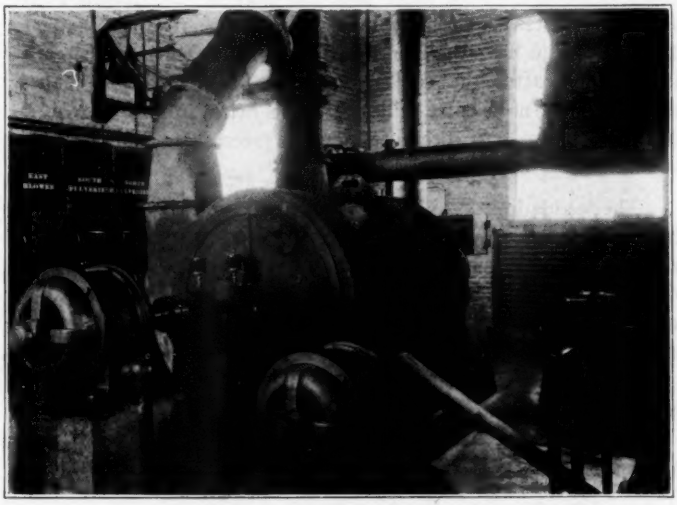


FIG. 5—DISTRIBUTION BLOWERS

they are enthusiastic advocates of the system. There is so little work involved that one of our superintendents operated two furnaces at a time, the furnaces being about 200 feet apart, and took off four heats per day, for many weeks. He did this to familiarize himself with the operation and to insure good results at the beginning. The laborious work incident to hand stoking and cleaning out ashes is entirely eliminated.

Effect on Refractories

In melting from three to four tons of iron per hour the life of the fire brick is just about the same as for hand fired

operation. At least this has been our experience operating under the very unusual conditions that prevailed during the past year and a half. We rather feel that under normal production conditions that the refractory cost per ton of melt will be about the same as for good hand fired practice when quick time is made. If the time is lengthened as for example to 5½ hours or to 6 hours for a 17 ton heat, the refractory cost will be almost half what it is for the quick heats. There is an economical point that can only be determined from exhaustive tests. Extremely intense heats are readily obtained. It is possible to have the iron, charged in a hot furnace, dripping five minutes after the coal is lighted. It is also possible to maintain such a heat as will cause the brick in the side walls to literally run. At present it would seem that our practice as outlined is economical.

The oxidation loss is certainly less with pulverized coal than with hand fired coal. In volume the slag is about half what it was for hand fired practice, although the percentage of scrap has been greatly increased. As an indication of better combustion conditions in a pulverized coal furnace than in a hand fired furnace, CO_2 readings may be of interest.

Below is given a comparison of CO_2 readings for hand fired and pulverized coal fired furnaces.

Hand Fired		P. C. Fired	
Per Cent CO_2	Time A. M.	P. C. CO_2	Time A. M.
	3:00—Fire started to heat furnace		3:00
	4:00—Started charging	14.2	3:30
	5:38—Finished charging	14.0	3:45
	5:40—Top blast on	14.0	4:00
9.2	5:45	13.0	4:15
11.2	6:00	13.0	4:30
10.4	6:15	13.0	4:45
10.6	6:30	16.0	5:00
11.0	6:45	16.0	5:15
14.4	7:00	16.5	5:30
13.0	7:15	16.0	5:45
13.6	7:30	15.4	6:00
13.6	7:45	16.0	6:15
12.0	8:00	16.0	6:30—Skimming
11.2	8:15	16.0	7:15
12.0	8:30	16.0	7:30—Skimming
13.8	8:45		7:50—Test
10.0	9.00		8:04—O. K. to pour

	Hand Fired	Powdered Coal Fired
10.8	9:15	8:45—Metal out
14.0	9:30	
12.6	9:45	
13.6	10:00	
	10:05—Start skimming	
11.0	10:15	
	10:18—Finished skimming	
10.6	10:30	
	10:40—Start skimming	
10.8	10:45	
	10:52—Finished skimming	
11.4	11:00—Start skimming	
	11:12—Finished skimming	
11.2	11:15	
11.6	11:30	
	11:35—Start skimming	
	11:44—Finished skimming	
10.6	11:45	
	11:47—O. K. to pour	
	11:57—Tapped	
	12:40—Metal out	

Melting times and charges may be compared as follows:

	Hand fired	Pulverized coal fired
Charge—total	24,000 pounds	32,000 pounds
Furnace	Cold	Cold
Charge—per cent pig iron	60	40
Melting time	8 hours 57 minutes	5 hours 4 minutes
Firing time	9 hours 40 minutes	5 hours 45 minutes
Tons melted per hour	1.34	3.16
Coal used	13,600 pounds	Not observed
Iron melted per pound coal	1.76 pounds	Not observed

Iron to Coal Ratios

Some hesitancy is felt in elaborating on iron to coal ratios. There are so many variable conditions to be taken into consideration that any statements made must be qualified else they may be incorrectly interpreted. In making comparisons with other foundries, it is advisable to get complete information if a true comparison is wanted. In hand fired practice the iron to coal ratio is simply the weight of the charge divided by the weight of the coal fired. However, even in hand fired practice it has been found that where it is the practice to preheat a furnace that has had a new bottom that the coal used for this purpose is not considered in the iron to coal ratio. If a comparison is to be of real value the quality and preparation of the coal should be taken into account.

With a pulverized coal operation, it is necessary to know the kind, quality and preparation of coal including an analysis and to also know where the coal is weighed. It is assumed that the coal is measured from the time the fire is lighted, either in a green or hot furnace, until the coal is turned off after all metal is out. The iron to coal ratios mentioned in this paper are based on the above premises—the coal being weighed before it is dried and truly represents the coal as received. The management is interested in the iron to coal ratio based on the coal as it is purchased, but moreover are they interested in the cost of coal per ton of melt or per ton of castings annealed.

Consider for the moment the moisture content. Most western coals run relatively high in moisture, but the moisture is paid for just as if it were pure carbon. Assuming a coal running 12 per cent moisture and that the melting ratio is 2 to 1 for the coal as received. If the coal is weighed after the moisture has been reduced to 2 per cent then the coal ratio for the dry coal would be 2.2 plus to 1 or an increase of 10 per cent. But this apparent increased ratio gives a false impression.

The preparation of coal, as previously explained, has an important bearing on the iron to coal ratio. It is possible to purchase lump coal with an ash content as low as 3 to 4 per cent and a B.t.u. value of from 14000 to 15000. Such coal pulverized would show an exceedingly high iron to coal ratio. However, screenings having an ash content of 12 per cent and a B.t.u. value of 11000 to 12000 might be much more economical, although the coal ratio would be much less. While we do not have figures to substantiate definitely the statement that the iron to coal ratio is directly proportionate to the B.t.u. value of coal of approximately the same volatile and fixed carbon content, yet we believe this to be true. Assuming this, then a coal containing 15000 B.t.u. should show a 25 per cent better coal ratio than a coal running only 12000 B.t u.

In giving iron to coal ratios it should be assumed that iron and coal has been actually weighed. The estimated weights

obtained by counting the revolution of a feed screw or by measuring the volume of pulverized coal in a bin should be considered of doubtful value and certainly should not be given out as accurate data. The iron to coal ratio is effected by the size of charge, kind of charge (per cent pig iron and scrap), firing time and quality of coal. It is assumed that the furnace is properly fired and that the iron is removed from the furnace in a normal manner.

So far the best iron to coal ratio obtained was 3.81 to 1. This ratio was the average of six heats averaging 23.6 tons each. This was not an experimental run, but the information was accurately obtained from the regular foundry practice. The coal used was Kentucky No. 1 as shown in Table No. 1. On another run of 10 heats averaging 25.06 tons the iron to coal ratio was 3.54 to 1. Another run of eight heats (all first heats) averaging 25.94 tons, the iron to coal ratio was 3.33 to 1. On a run of 4 heats averaging 13.5 ton the ratio was 2.81 to 1.

A series of tests were run on representative coals with a view of establishing the value of the coal on a B.t.u. basis. Results from three of these tests are shown below: The average charge was 25,500 pounds and the heats were all taken off in cold furnaces. The iron to coal ratios are consequently relatively low. In these particular tests, we were especially desirous of having uniform operating conditions, so that the results would be comparative.

Coal	Ky. No. 2	Ky. No. 3	Ky. No. 1
Preparation	R. M. R.	N. P. & S.	N. P. & S.
Ash per cent	6.18	8.15	12.12
B.t.u. per pound dry	13913	13131	12694
Iron to coal ratio	2.69	2.65	2.60
Kilowatt-hours per ton to pulverize	14.88	15.20	17.80
Kilowatt-hours per ton to pulverize and distribute	49.93	50.25	52.85
Kilowatt-hours per 1,000,000 B.t.u. pulverized and distributed	1.71	1.91	2.07

The cost of Kentucky No. 3 and Kentucky No. 1 delivered was the same. The price of Kentucky No. 2 was 25 per cent higher than Kentucky No. 3 or Kentucky No. 1, but was worth to us from 10 to 15 per cent more. Since the Kentucky

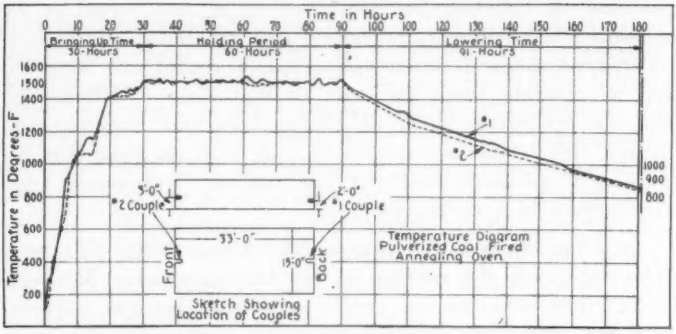


FIG. 6—TEMPERATURE DIAGRAM OF PULVERIZED FIRED ANNEALING OVEN

FIG. 7—VIEW SHOWING POWDERED COAL EQUIPMENT FOR A BATTERY OF ANNEALING OVENS

No. 3 coal was from a reliable company and it was worth to us about 8 per cent more than Kentucky No. 1, yet cost no more, it was to our advantage to purchase the Kentucky No. 3.

Annealing Ovens

Pulverized coal has been used for firing annealing ovens for many years. It has proven so satisfactory that a number of foundries have found it to be economical and satisfactory in every other way. In the early installations, the coal was not ground very fine and in these installations the method of handling the coal to the furnaces was not conducive to good operation. The later installations provide pulverizers and equipment for grinding the coal to the fineness recommended for metallurgical furnaces and which is mentioned elsewhere in this paper. Conveying of the coal either by compressed air or suspended in air provides for the transmission of the coal to the furnace in a proper condition for burning and eliminates the difficulty that was experienced with coal dust being scattered over the buildings through which the coal was transported.

The temperatures are easily controlled. Fig. 6 shows a temperature diagram for an annealing oven. Thermocouples were located as shown by the sketch. The oven was charged with 35 tons of castings and packed in pots in the usual manner. You will note from this diagram that the bringing up time was 30 hours to 1500 degrees. The holding period was for 60 hours and it is interesting to note the close regulation of the temperature in the front and back of the oven, the couples being approximately 33 feet apart. The lowering time to 850 degrees was 91 hours. The total firing time was 90 hours. This record was plotted from information observed hourly during the entire cycle and may be considered a representative performance. One operator can take care of a large number of ovens, particularly if the ovens are equipped with pyrometers located in a central station. The coal or air valves must be adjusted occasionally, in order to maintain the temperatures uniform. The temperature of an oven may run along uniformly for a considerable period and then the tem-

perature may go up or down either at the front or the back. In order to correct this, either the air or the coal valve may be adjusted. These fluctuations may be due to irregular feeding of the coal or it may be due to the difference in the quality of the coal. We find that coal varies considerably in ash and B.t.u. value, when the samples were taken from the same car. It is due to this variation in the quality of coal that adjustments of the valves are necessary, in order to maintain uniform temperatures. During the holding period, very little coal is necessary to maintain the temperature and consequently even a slight change in the quality of the coal will be reflected in the temperature of the oven.

An annealing oven fired with pulverized coal is under pressure as contrasted with a minus pressure or vacuum in a hand fired oven. The air in the oven is permeated with very fine ash which covers the pots and the walls. If there should be a slight leak at any point, there is a tendency to force this ash through these very small openings. The ash is retarded at these points and eventually the crevice is filled and the leak stopped. With a hand fired oven these leaks tend to grow larger since only air from the outside is being drawn into the oven. The supply of air into an annealing oven fired with pulverized coal can be controlled since air is only admitted with the coal through the burner.

Wtih a hand fired furnace, the amount of air entering an oven is dependent on the number of times the fire door is opened, the length of time it is held open and is effected by the leaks. Then too, coal is fired on the grates and after the desired temperature has been reached so little coal is used that generally a considerable excess of air is permitted to enter the fire box, in order to maintain a fire and frequently the dampers are opened to permit the escape of heat, in order to maintain proper temperature.

When pulverized coal was first installed for annealing oven firing, we anticipated considerable trouble from the ash deposit. Our ovens were arranged with a net work of flues under the floor and it was thought that these flues would quickly become filled. After more than a year's operation, we found it unneces-

sary to clean the flues and apparently the passages have not been obstructed to a point where the operation of the annealing ovens is effected. With the decreased amount of coal burned during an annealing cycle and with the lower temperature and volume of the discharged gases, we do not feel that the flues under the floor are worth while maintaining. In applying pulverized coal to our ovens, the fire boxes were removed from the sides, the walls bricked up and the burner installed in the end of the oven opposite the doors. No other change was made. We believe, however, that some changes can be made that will improve the economy and permit the temperature to be controlled within close limits with less attention on the part of the attendant.

Iron to Coal Ratios in Annealing Practice

The iron to coal ratios in annealing practice vary with the size, type and construction of oven, charge, kind and preparation of coal and, of course, on the intelligence displayed by the attendant. A record of some tests may prove to be interesting.

Test No.	Field	Coal Ash per cent	Moisture per cent	B.t.u. As Rec'd	Volatile per cent	Weight of Charge Pounds	Iron to Coal Ratio	Total Firing Time In Hrs.
1	Ky.	12.12	2.53	12373	31.56	78262	3.93	84.50
2	Ky.	6.18	2.37	13589	34.09	76625	3.74	87.25
3	Ind.	9.07	8.02	11119	34.93	71053	2.81	88.75
4	Ky.	8.09	2.94	13320	32.03	70158	3.48	84.90
5	Ky.	8.15	3.21	12700	35.33	61860	3.16	84.00

The best iron to coal ratio obtained so far was 4.28. With the same ovens, hand fired, the iron to coal ratio was 2.02.

For firing boilers, pulverized coal has many advantages over hand fired coal. Under normal operations, steam is generated by waste heat gases from the melting furnaces. A test was run to establish our steam requirements. As the boiler was fired with pulverized coal, some of the results may prove of interest.

Duration of test .....20 hours
Water actually evaporated per hour .....24131 pounds
Factor of evaporation 1.0429
Equivalent evaporation per hour from and at 212 degrees..25166 pounds

Builders rated horse power	400
Per cent builders rated horsepower developed	182.5
Equivalent evaporation from and at 212 degrees per pound coal as fired	10.23
Efficiency of boiler (dry coal)	.795

In discussing the use of pulverized coal, with foundry executives and engineers, who have not had direct experience with it, there are many times statements expressed which indicate what might be considered, a prejudice against the practice. In analyzing these statements, it is found that they are based on hearsay evidence, or on the results of experiments conducted many years ago. The failures are generally mentioned; the successful installations seldom. Some of the points most frequently discussed are listed below and our experience briefly noted under each heading.

Ash

The ash and slag from pulverized coal furnaces has been analyzed a number of times and in not one case has there been reported any combustible present. This, we believe, clearly demonstrates that we are not having any loss of coal in the ash. Contrast this with hand fired practice or even go to the trouble and slight expense of having an analysis made of the B.t.u. value of the ash from either a melting furnace or annealing oven and you may be surprised to learn the loss that is occurring every day. The non-combustible portion of the coal must be disposed of regardless of the manner in which it is burned. The particles of ash with pulverized coal are extremely small and a certain percentage of the ash passes out through the stack and disappears. After seventeen months operation, we have been unable to find a trace of ash that has passed off through the stack either about our plants or in the vicinity of the plants.

In melting furnaces, a certain portion of the ash becomes a part of the slag and is skimmed off with the slag. A portion of it is deposited at the base of the stack and this amounts to about one wheel barrow load for two heats of 20 tons each. What percentage of the ash actually passes out of the stack, we have not made any attempt to determine, but it certainly is not objectionable. In the annealing ovens, because of the low

temperatures maintained, there is practically no slag made. There is a deposit of ash in the annealing ovens, but this does not seem to be any greater in volume than in a hand fired oven. In stationary boiler operation, the slag drops to the bottom of the combustion chamber and some problem is involved in taking care of this deposit. It is very brittle when cold, but pasty when hot. The most satisfactory way to take care of this slag seems to be to have the slag dropped through openings in the bottom of the combustion chamber into a receptacle filled with water. With a combustion chamber of proper design, no difficulty is experienced with a slag formation on the boiler tubes and there is very little ash settles on the tubes. It does not seem to be necessary to blow this ash much more frequently than when the boilers are fired by hand. The ash is readily removed with the ordinary soot blowers.

Smoke

When a furnace is first started there is some black smoke. After ten or fifteen minutes, the stack clears and from then on there is only a light haze issuing from the stack and this we feel is practically all ash. We doubt, however, whether the solid particles in this haze is greater in amount than is contained in the smoke that generally issues from a stack. We certainly know that it is less objectionable. At one of our plants, the residents in the vicinity made it a practice to keep all windows closed when the wind was blowing in a certain direction. They now say that since pulverized coal has been used, that this practice is unnecessary and they can have the windows open regardless of which direction the wind is blowing. In two cities where we have pulverized coal plants, the smoke inspectors have been greatly pleased with the changed conditions brought about since the installation of the pulverized coal plants.

Melting Time

As mentioned in other parts of this paper, the melting time in our foundries has been greatly reduced. Instead of having firemen report for work at from 12 midnight to 2 a. m. when two heats are to be taken from a furnace, they can now report at 6 a. m. and with very little effort, but some

intelligence, have the iron melted by the customary time. The length of time, while dependent on the operator, yet it does not require additional physical exertion on the part of any one to make up for poor coal or any other of the variable conditions encountered in everyday foundry operation.

Brick Work

In melting furnace operation, this subject is covered in another part of the paper. There is certainly no greater wear on the brick work in annealing ovens and we doubt if there will be as much. There are no fire boxes to be maintained with pulverized coal.

Condition of Iron

The iron is hotter than in hand fired practice and it can always be poured at approximately the same temperature.

Fire Hazard

Where coal in any preparation is stored, there is a fire hazard. In our plants, all coal, as received, is stored near the pulverizer plant. All pulverized coal is stored in the pulverized coal building. There is no coal stored in any other building. Pulverized coal will burn or explode when mixed with a proper amount of air. It will burn slowly when ignited by spontaneous combustion. We have had one fire in each of our foundries, neither of which, however, was serious nor gave any particular trouble. The first fire was caused by drying the coal at too high a temperature. The coal ignited in the dryer and was carried into a small storage bin, located between the pulverizers. It was quickly discovered and the coal was removed from the bin. The other fire was caused by pulverized coal igniting from spontaneous combustion in one of the storage bins. At this time, the plant was shut down. In anticipation of resuming operations, some coal was pulverized. We did not resume operations at the anticipated time and the coal was left in storage for eight days, at which time it was found to be ignited. It was only necessary to run the coal out of the storage bin to eliminate the fire.

Prevention of Packing

When pulverized coal is first delivered to the storage bin it carries a good percentage of air. It may be described as being "quiverish." In this state it will flow freely. If it remains undisturbed, the air gradually separates from the coal and the coal "packs." It sometimes packs so solidly that it will form a bridge over a feed screw. Agitators inside the bin are sometimes used to prevent this packing. Air vibrators are sometimes attached to a bin to "break the bridges." While a vibrator will "break a bridge" it also has the effect of causing the coal to pack more solidly. To prevent the coal from packing, and thus avoid the fire hazard incident there to, in the storage bin of a circulating system, it is only necessary to start up the disturbing blower and circulate the coal even though no furnaces are in operation. Should a plant be shut down with pulverized coal in storage, it can be circulated every two or three days with little expense.

Escape of Dust

The pulverized coal plant should be and can be kept clean and practically free from coal dust. With the air separation type of pulverizers, all pulverized coal is enclosed in a practically air tight system consequently, if the joints are properly maintained, there is no reason why coal dust should be permitted to escape into the building. If coal is transported by open belts or by open bucket elevators, not fully protected, there will be coal dust in the plant. This, however, is a problem of design and should be considered carefully. Our pulverizer plants usually are fairly free from coal dust and when they are not, it is only necessary to find the leak and eliminate it. In such systems as we have installed, coal is transported in spiral steel riveted pipe. Leaks in this pipe are easily located and corrected. There is little danger of coal being scattered about the buildings through which these distributing pipes pass.

Effects of Sulphur

Some authorities contend that with pulverized coal the sulphur burns to SO_2 gas and passes out of the stack. This theory we have been unable to verify. We now believe that

high sulphur coal is as objectionable when burned in the pulverized form as when burned in lump form. Our data in this regard for hand fired practice is very meager, consequently we cannot make direct comparisons. A test made recently with coal showing 1.28 sulphur by analysis produced iron with a sulphur content of .086.

Operating Labor

In a pulverized coal plant of five tons per hour capacity, three men, two for day time and one for night are necessary to man the pulverizer building. In addition to starting the machinery, they inspect the crusher and elevator occasionally; remove steel from the magnet; fire the dryer furnace; inspect the pulverizers and generally satisfy themselves that all parts are functioning properly. They also make such repairs as are within their range of experience. At a melting furnace only one man is required and he has very little manual labor to perform. There is no coal to handle and very little ash to dispose of and about half as much slag. In the annealing room there is very little labor required. One man can attend to eight or ten ovens with but little effort. There is no coal to be handled, no ash to be disposed of and no fire boxes to be maintained.

Life of Annealing Pots

While we believe that annealing pots have a much longer life, we have no definite figures to substantiate such a statement. The flame being less oxidizing ought to prolong the life of the pots.

Annealing Time

We are not advocates of a short anneal cycle. The bringing up time can be from 10 hours upward, but 30 hours seems to be a satisfactory time. In this time the warping is eliminated or is at a minimum and the heat has an opportunity of permeating all pots and castings. The holding period of from 60 to 70 hours seems advisable. There is no reason why this should be changed by the use of pulverized coal.

Maintenance Cost

Our plants have not been in operation a sufficient length of time to establish maintenance costs. In a paper presented

before the meeting of the American Society of Mechanical Engineers in Detroit in 1919, Mr. Harrison reported the maintenance cost as being from seven to ten cents per ton of coal handled. While we have no figures to verify this estimate, yet we believe it to be fair.

Advantages

Some of the advantages of burning pulverized coal in a foundry are listed below:

First—Saving in fuel.

Second—Ability to burn almost any kind of coal of any preparation. We have actually used Ohio, Indiana, Kentucky, Pennsylvania and West Virginia bituminous coal of egg, lump, mine-run and screening preparation.

Third—Screenings or mine-run coal can be used regularly in preference to lump coal and the difference in cost saved.

Fourth—Saving in labor in handling coal to the furnaces and elimination of coal storage in various parts in the foundry and annealing room. This means an increased valuable floor space available for other uses.

Fifth—Decreased furnace repairs if extremely quick heats are not wanted.

Sixth—Saving in firing labor.

Seventh—Decreased pot expense on account of less oxidation.

Eighth—Decreased time for taking off heats and for completing the annealing cycle.

Ninth—Temperature readily controlled, which in the annealing cycle means shorter time to get up the temperature and uniformity in maintaining temperature.

Tenth—Savings due to using an increased amount of scrap in the charge because of less oxidation.

Eleventh—Freer running metal which results in fewer misruns and consequently lower foundry loss.

Twelfth—Elimination of smoke because of nearer complete combustion.

Disadvantages

To offset these advantages, there are the following disadvantages:

First—Cost of plant and equipment.

Second—Operating costs of the plant.

Third—Interest on the money invested and depreciation of the plant and equipment.

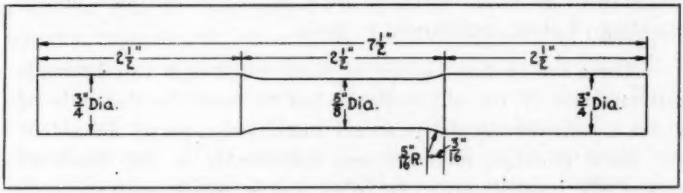
We feel that the advantages far outweigh the disadvantages if such they can be called. If maximum results are to be obtained from pulverized coal equipment, it should be borne in mind that exacting practices must be established and sufficient supervision given to be assured that the practices established are being intelligently followed. The success of an installation is dependent on the intelligent co-operation of the foundry supervisory force. There is nothing mysterious about pulverized coal or its application to furnaces, but to get good maximum results it requires intelligent investigation and analysis and supervision. These premises are no different from those prevailing under hand fired operation, but because pulverized coal method is different from established practice, it is sometimes considered as being governed by principles different from those with which all foundrymen are familiar.

Report of A. F. A. Committee on Specifications for Malleable Iron Castings

The committee on Specifications for Malleable Iron Castings, appointed to co-operate with Committee A-7 of the American Society for Testing Materials, begs to report as follows:

A joint meeting of the A. S. T. M. Committee A-7 and the A. F. A. Committee on Specifications for Malleable Iron Castings was held on April 3, 1922, and it was recommended that the present specifications be changed as follows:

The ultimate strength to be increased from 45,000 to 50,000 pounds per square inch and the elongation from 7.50 to 10 per



DIMENSIONS OF PROPOSED TEST BAR

cent; that the over all length of the bar be decreased from 12 to 7½ inches, and the gage length, including fillets, from 6 to 2½ inches; the diameter of the grip ends and gage length to remain ¾ and ⅝ inch respectively.

To paragraph 6 (b) the following sentence was added: "In case one of the retest bars contains a flaw which results in the failure of the bar to meet specifications, at the discretion of the inspector, additional test bars from the same oven may be tested, or test bars may be cut from castings."

W. R. BEAN
A. E. HAMMER
W. G. KRANZ
R. A. NOURSE
A. E. WHITE
ENRIQUE TOUCEDA, *Chairman*

Technical Control of the McCook Field Foundry

By E. H. Dix Jr., Dayton, O.

Until recently the foundry has not received earnest consideration from scientific and technically trained men. For example, it is only within the past few years that it has been possible to measure the temperature of molten metals by a satisfactory method. Even at the present time, the old time foreman is skeptical as to the real paying value of technical methods. In part this attitude is just, because there have been many instances where new methods have been tried and discarded, perhaps through faults, through lack of a thorough understanding of their application, or both.

There are certain classes of work which still can be made satisfactorily by the old methods, but to meet the demands of aircraft construction the practical foundryman needs the aid of the latest scientific methods and instruments in the hands of technically trained men. In other words, strict technical control must be exercised in the foundry as it is in the heat-treating room and in other branches of industry.

In order that the Engineering Division of the Air Service might obtain information relative to foundry problems at first hand, a small experimental foundry was established at McCook field, Dayton, O. At first the work consisted chiefly of experimenting with the test bars of various nonferrous alloys. It soon was realized, however, that in order to be of practical value, the scope of the foundry would have to be enlarged so as to make actual castings of the alloys experimented with. From this it was a short step to supplying all of the nonferrous castings for the large machine shop building experimental parts for aircraft. Patterns of dubious design are tried out in this foundry and the difficulties remedied before the work is let out on contract.

As the foundry is under the direct supervision of the Metallurgical Branch of the Material Section, it has at its disposal the services of technically trained men and all of the latest equipment. As a result, a system of technical control has been built up which should be of more than passing interest to the practical man, even though the demands on his product may be less exacting.

Melting Equipment

The melting equipment of the foundry is shown in Fig. 1. From left to right these furnaces are: A Monarch-type No. 20, stationary crucible furnace, a Hausfeld-type No. 400, crucible tilting furnace, and an Iler-type No. 40, stationary crucible furnace, all arranged for oil or gas fuel. Recently a 10-inch electric crucible was installed. This is shown in the foreground of Fig. 2. This furnace is a recent development of the induction type electric furnace, the heat being generated directly in the metal by a high frequency current. For metals of high conductivity, such as copper and aluminum, a special crucible is used and in this case the crucible walls are heated by the induced current. This furnace is capable of attaining exceedingly high temperatures and is desirable for the manufacture of hardeners containing metals of high melting points. An electrically-heated core oven with thermostatic control may be seen at the extreme right of Fig. 1. This oven is desirable for experimental core work.

The Four Divisions of Technical Control

The technical control of the foundry may be grouped under the following headings: Temperature control, chemical analysis, physical testing, and metallographic examination. These four headings will now be discussed separately.

Temperature Control

The advantage of careful temperature control cannot be too strongly emphasized. The maximum furnace temperature and the pouring temperature strongly influence the structure and physical properties of all metals and alloys. This is particularly true of aluminum alloys in which case it is known that the lower

FIG. 1—MELTING EQUIPMENT AT THE McCOOK FIELD FOUNDRY

the pouring temperature, the more dense the structure and the stronger the alloy. It is true that the experienced melter handling the same metals day after day becomes expert in judging temperatures, but there can be no doubt that differences in atmospheric conditions will cause even the most experienced to fall down at times in judging the correct temperature of the metal. For instance, a pot of aluminum alloy which looks red in the comparative darkness of the furnace room assumes a dull silvery lustre when taken out into the sunlight. Bright and cloudy days produce corresponding differences in the appearance of the metal. Also, where a number of different alloys are handled, the judgment of the correct temperature becomes increasingly difficult.

It is possible at the present time to measure the temperature of molten aluminum satisfactorily in several different ways. The ordinary base metal thermocouple wire may be used in a light wrought iron or cast iron protecting tube. This is satisfactory if the thermocouple is to be allowed to remain in the bath of metal, as for instance, in holding furnaces. However, if a quick reading is desired, the protecting tube produces too great a lag and is not satisfactory. For a quick reading, an iron constantan pyod has been found satisfactory. This is made up of a constantan wire enclosed in a light iron tube and welded to it at the end; thus the iron tube acts as one element of the thermocouple and at the same time as a protecting tube. Although the manufacturer does not recommend its use in molten aluminum without a protecting tube, it has been found in our foundry to give satisfactory results. Recently we have been using chromel-alumel wires of No. 6 gage without any protecting tube. These wires are spread apart above the weld about 4 inches so as to prevent short circuiting through the metal. The weld, of course, burns off after a number of readings have been taken, but the wires can be re-welded until completely used up. This couple gives an even quicker reading than the pyod but it is liable to error due to short circuits across the metal.

For measuring the temperature of brass and bronze, the

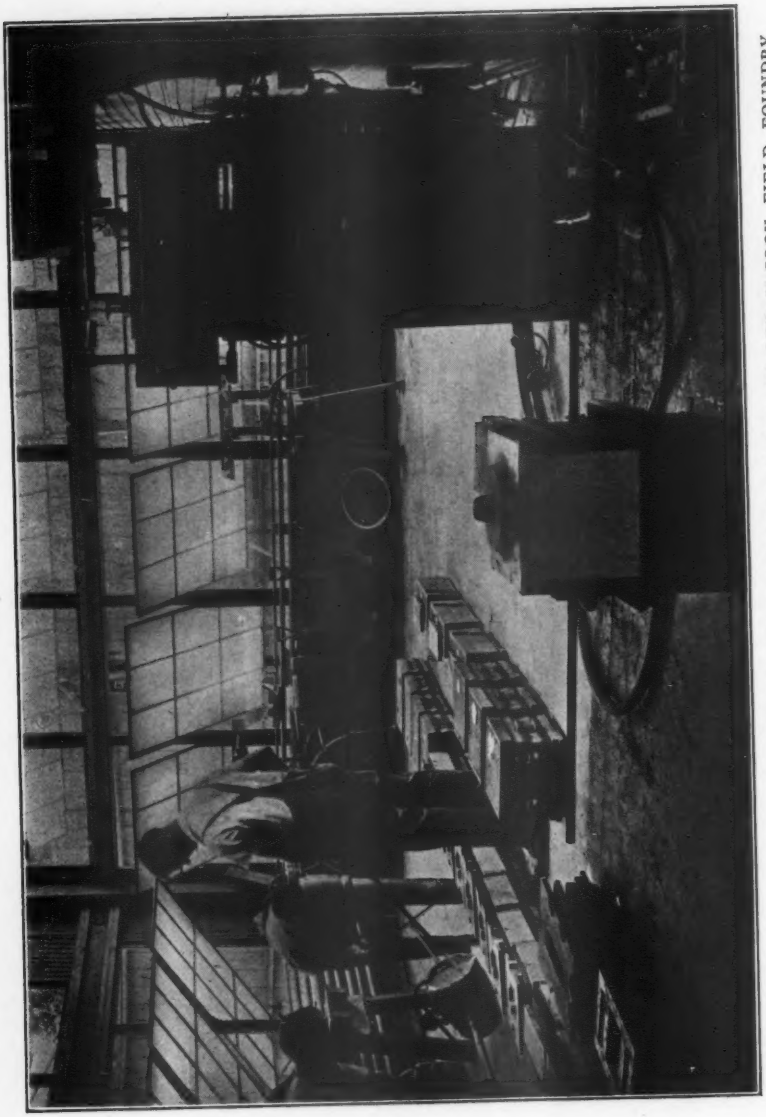


FIG. 2—ELECTRIC CRUCIBLE FURNACE AND MOLDING FLOOR IN THE McCOOK FIELD FOUNDRY

protecting tube presents a much greater problem inasmuch as the temperatures are higher and it is difficult to obtain an alloy which will not be attacked by the brass or bronze. However, a chromon tip protecting tube recently has been perfected which gives highly satisfactory results. Any type of base metal couple can be used in the tube, but in our foundry the chromel-alumel wire is used exclusively.

All of these couples are used in conjunction with a Hoskins-type millivolt meter of the high resistance type. Flexible leads of the same material as the couple are used so that the cold junction is carried to the meter. The meter is located in a relatively cool place so that the error caused by cold junction variations is small. The couples are frequently checked by the freezing point of salt. Fig. 1 shows the temperature of a pot of aluminum being taken, using the chromel-alumel couple.

The following maximum furnace temperatures and pouring temperatures have been adopted for the usual run of work, although, of course, they are varied to suit unusually heavy or very thin castings:

Alloy	Melting point liquidus, deg. Fahr.	Maximum furnace temperature deg. Fahr.	Pouring temperature deg. Fahr.	
Cu 8, Al 92	1148*	1400	1200	1300
Cu 10, Al 90	1130*	1400	1200	1300
Cu 85, Sn 5, Zn 5, Ph 5	1780**	2000	1950	
Cu 88, Sn 10, Zn 2	1825**	2200	2050	
Cu 80, Sn 10, Pb 10	1735**	1950	1900	
Cu 60, Zn 37+3 Hardener	1600**	1800	1700	1750

*From the equilibrium diagram given in the Bulletin of the American Institute of Mining and Metallurgical Engineers, No. 150.

**From *Technical Paper* No. 60 of the Bureau of Mines.

Chemical Analysis

The chemist is essential for the satisfactory operation of the foundry. He carefully analyzes the raw material which is always purchased according to definite chemical specifications. He analyzes the rich alloys made up for introducing metals of relatively high melting points and the proportion in which these

hardeners are used is based on his analyses. Finally, he analyzes the alloys as mixed to determine if the metals are in their proper proportion and to see that an unduly large amount of impurities has not been introduced during the melting.

Physical Testing

The physical testing laboratory furnishes the ultimate check on the quality of metal produced. Unfortunately, it seldom is possible to test the actual castings produced in the foundry because to do this would be to destroy the casting. It therefore is necessary to make tests on special bars cast from the same metal, and therein lies the greatest difficulty in connection with the testing of casting alloys, that is, to obtain a specimen truly representative of the metal. Many erroneous conclusions have been drawn through the use of faulty test bars. It is the usual practice with large castings to cast, as an integral part of the casting, a coupon from which is machined the test bar. This test bar is required to meet certain physical specifications. The experienced foundryman knows that he can obtain various physical properties in the test bar, depending upon its location with respect to the gates and risers. Thus, to meet a certain specification it is merely a game for the manufacturer to select the position on the casting which will allow the test bar to meet the specification. Specifications usually read that the location of the test bar shall be agreed upon between the inspector and the manufacturer, but of course the manufacturer, having much more experience in this connection, can easily persuade the inspector that his selection is the correct place for the test bar. Thus, instead of being concerned with improving his product to meet the specification, he is dodging the specification by out guessing the inspector.

For the past year, the Material Section has been much concerned with standardizing the method of casting the test bars of the nonferrous alloys used in aircraft construction and has adopted several which have been found to give satisfactory results. The choice of a method of casting test bars should be based on simplicity, uniformity of results, and results as

nearly as possible comparable to values obtained in actual castings. In regard to this last item, it must be realized that no test bar can represent the physical properties of different parts of a casting because physical properties vary from section to section, depending upon the thickness, the proximity to gates and risers and upon whether in the bottom or top of the casting. After taking all of these things into consideration, it has been decided that the separately cast test bar is much more satisfactory than the bar which is cast as an integral part of the casting. By adopting a separately cast test bar the method of gating may be specified once and for all, and this cause for disputes between the inspector and the manufacturer will be eliminated. By adopting a uniform method, data will gradually be accumulated which will result in fair specification values for different alloys.

In order to furnish information for the designers, it is the policy of the foundry from time to time to cut small test bars from castings and to compare physical properties of these with the results obtained from the standard test bar cast from the same melt. These tests give average figures which are satisfactory for parts designed with a large factor of safety. However, in the design of aircraft parts, it is always necessary to reduce the weight to the absolute minimum; therefore, the castings must be designed with a more intimate knowledge of the physical properties obtained. The following procedure is suggested for important castings which are highly stressed. The casting is designed and the pattern made up from the best available knowledge of the physical properties of the alloy to be used. This pattern is then turned over to the foundry and three or four castings made, using as many different methods of gating as may be deemed necessary. These are all poured from the same melt of metal from which is also poured a mold of standard test bars, and the pouring temperature carefully noted. It sometimes may be necessary to try several pouring temperatures in order to select the one giving the strongest and soundest castings. The castings then are tested in a manner which

duplicates the service condition as nearly as possible. From the results of these tests it is possible to decide whether the casting is strong enough to meet the requirements for which it was designed and at the same time to determine which method of gating gives the best results. If one of the methods of gating produced a casting which would satisfactorily meet the requirements, then it is merely a matter of seeing that all castings

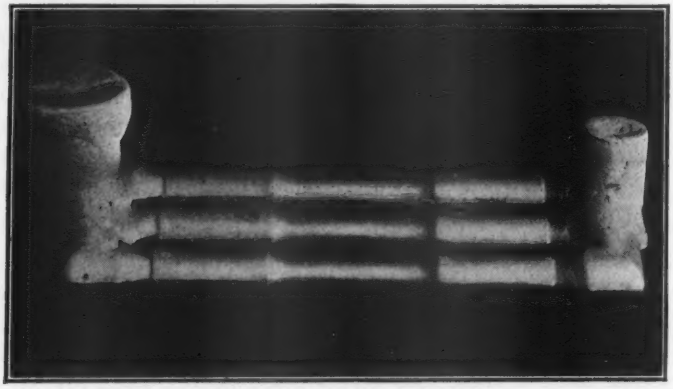


FIG. 3—METHOD OF CASTING ALUMINUM ALLOY TEST BARS

on that order are gated in the same way and poured at the same temperature and that the standard test bars cast from each melt are at least as good as the test bars cast from the experimental heat.

Fig. 3 shows the methods of casting test bars of aluminum alloys, which has been definitely adopted by the foundry for all experimental and inspection work. This method is simple, requires a small amount of metal, and gives uniform and dependable results, which, while usually slightly higher than test bars cut from castings, yet are not sufficiently high to be misleading to designers. The middle bar may be omitted if desired. This same method is being used for red brass and gun metal. It seems to be perfectly satisfactory for red brass, but with gun metal it has been noted that the middle bar is frequently much

stronger than the two outside bars. It is suggested that the reason for this is that the metal flows directly from the pouring head down through the middle bar and does not flow into the two outside bars until it begins to back up in the riser. Recently a number of comparisons have been made between the test bars cast in this manner and those cast from the same pattern, but with the middle bar stopped off, and it has been found in every case that with the bars cast two in a mold the two results are uniform and consistently as high as the middle bar of the mold where three are cast together. One or both of the outside bars of this latter mold are usually low.

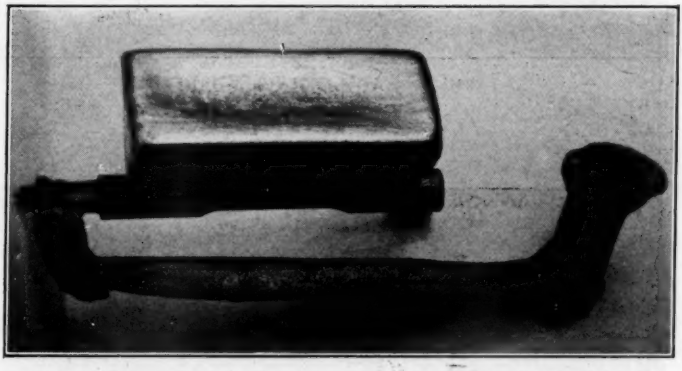
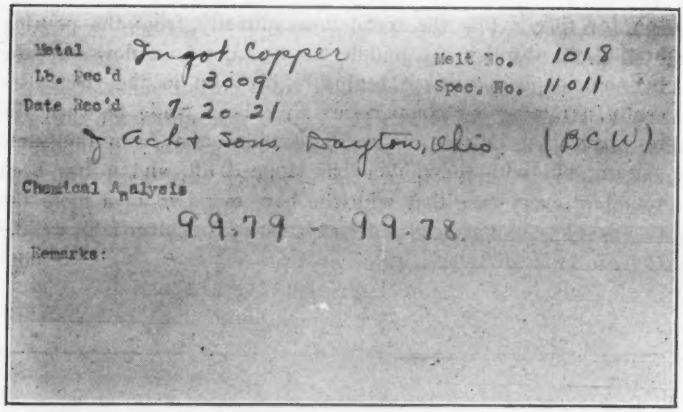


FIG. 4—METHOD OF CASTING MANGANESE BRONZE TEST BARS

Fig. 4 shows the method adopted for manganese bronze and other high shrinkage alloys after a great deal of experimenting. The complete results obtained in these series of experiments may be found in a paper by the author presented at the 1921 meeting of the American Society for Testing Materials.

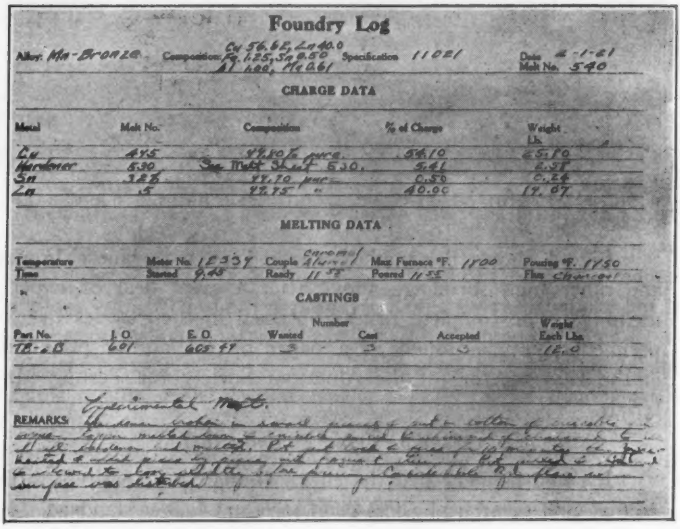
Metallographic Examination

It often happens that the chemical analysis is entirely satisfactory and yet the physical properties are below standard. In such cases it is necessary to turn to the metallographic exami-



Metal Ingot Copper — Melt No. 1018
Lb. Rec'd 3009 — Spec. No. 11011
Date Rec'd 7-20-21
J. Ackt Sons, Dayton, Ohio (BCW)
Chemical Analysis
99.79 - 99.78.
Remarks:

FIG. 5—METALS STOCK CARD



Foundry Log

Alloy Ma-Bronze — Composition Cu 56.62, Zn 40.0, Fe .125, Sn 0.50, Al .100, Mn 0.61 — Specification 11021 — Date 2-1-21 — Melt No. 540

CHARGE DATA

Metal	Melt No.	Composition	% of Charge	Weight Lbs.
Cu	495	99.80% pure	56.10	6.51.10
Manganese	530	Sp. Wgt. Shot 6.30.	5.61	0.58
Sn	525	99.10 pure	0.50	0.24
Zn	15	99.75 "	40.00	17.07

MELTING DATA

Temperature — Meter No. 1E337 — Couple Chromel/Alumel — Max Furnace °F. 1700 — Pouring °F. 1950
Time — Started 9.40 — Ready 11.35 — Poured 11.55 — Flux Charcoal

CASTINGS

Part No.	I.O.	E.O.	Number Wanted	Cast	Accepted	Weight Each Lbs.
TR-2B	601	605 FF	3	3	3	18.0

REMARKS: Experimental Melt.
The room temperature record was not taken at the time of pouring. Upon melting down a small amount of charge for the chromel-alumel thermocouple, it was found that the couple was broken. Put in new couple and poured at 1950°F. Heated a little more to pour with faster stream. Put gate on #3 to see if would be less shrinkage. Solar pouring. Considerable B.S. flaws on surface was sandblasted.

FIG. 6—FOUNDRY LOG SHEET

COMBINED DATA SHEET FOR CASTING ALLOYS

FOUNDRY RECORD

ALLOY Mn Bronze — DATE CAST 2-1-21

COMPOSITION Cu 56.6, Zn 40.0, Fe 1.25, Sn 0.50, Al 1.00, Mn 0.61 — MELT NO. 840

SPECIFICATION NO. 11021 — J.O. 601 — E.O. 605-42

Charge:

Material	Melt No.	Composition	% of Charge	Weight Lbs.
Cu	496	99.80 pure	54.10	25.80
Hardener	530	See below	5.41	2.58
Sn	526	99.70 pure	0.50	0.24
Zn	5	99.95 pure	40.00	19.07
		Total		47.69

Flux: None

Furnace Tilt Fuel Oil Time in Furnace 2 hrs. 10 min.

Max. Fur. Temp. °F. 1800 Pouring Temp. °F. 1750 Test Bar Pattern No.

Remarks: Analysis of Hardener Cu 46.6; Mn 11.33, Fe 23.10, Al 18.90.
Bars cast with 1/4 in. gate.

Approved: E. H. Dix, Jr.

TESTING RECORD

Date Tested 2-3-21

Specimen marked	1	2	3	Aver.	Aver.
Type of Specimen	Machined - Th'd End				
Orig. Dia. In.	.502	.502	.502		
Yield Point, Lbs. sq. in.	45,470	38,900	34,360	39,580	
Tensile St'h, Lbs. sq. in.	83,770	83,370	84,480	83,960	
Elong. in 2 in. %	22.5	20.5	23.5	22.2	
Red. of Area %	24.44	23.89	26.89	25.01	
Location of Fracture	M.T.	O.T.	O.T.		
Character of Fracture					
Brinell @ 500 kg.	156	156	159	157	
Scleroscope	24	24	24	24	
Specific Gravity	8.24				

Remarks:
O.T. Outside Third
M.T. Middle Third

Approved: R.R.Moore

CHEMICAL ANALYSIS

Element	Cu	Sn	Mn	Fe	Al	Zn
	56.80	0.57	0.47	1.14	0.99	40.0 Dif.
	56.84	0.57		1.14		
Remarks:		0.59				

Approved: A.C.Zimmerman.

FIG. 7—COMBINED DATA SHEET

METALLOGRAPHIC RECORD

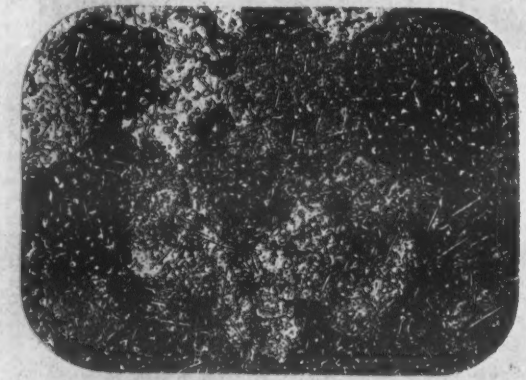


Plate No. 2111-A
100 X

Etching $NH_4OH + H_2O_2$

J. O. -- E. O. 605-2
Composition Cu 56.82, Zn 40.0, Sn .58,
(As Mixed) Mn 0.47, Fe 1.14, Al 0.99,
(Analysis) Fict.Zn 46.0

Melt No. 540 Spec. No. 1
Pattern No. TB-2B
Pouring Temp. ° F. 1750

Yield Point, lb. / sq. in.	45,470
Ten. Str., lb. / sq. in.	83,770
Elongation, %	22.5
Red. of Area, %	24.44

Brinell 156 Scler. 24

DESCRIPTION:

Alpha particles precipitated from grains originally beta. "Purple Constituent" noted at 1000 X.

FIG. 8—METALLOGRAPHIC RECORD CARD

nation of the alloy for an explanation. This subject is far too broad to permit a discussion at the present time, but it may be stated that the foundry obtains microphotographs of the structures of test bars as a matter of routine record. These are carefully filed and in the course of time will furnish satisfactory information relative to the value of metallography as a branch of technical control of the foundry.

Correlation of Tests

The most important part of the technical control is the correlation of the four branches just discussed. This can only be obtained by careful and accurate records. The forms used in the foundry are reproduced in Fig. 5 to 8. Fig. 5 is the stock card. As soon as metal is received from the outside or made up in the foundry for future use, it is entered on this card. It is identified by a melt number. The melt numbers are consecutive numbers given to each pot of metal melted in the foundry or each lot of materials received from the outside. The complete information relative to any melt is given on the foundry log sheet, having the corresponding melt number. This form is shown in Fig. 6. Fig. 7 is a combined data sheet containing the information from the foundry log, the physical test results, and the chemical analysis; thus, the full information is contained on one sheet and it is not necessary to look through several sets of files in order to obtain this information. Fig. 8 shows the form used for the metallographic record. This also contains the physical properties and chemical analysis of the specimen photographed.

Conclusions

In conclusion, let it be definitely realized that technical control is a tool to aid the practical skill of the foundryman; it is not black magic which can replace long years of toil over the fires. Implicit faith in the pyrometer may lead to more rejected castings than the total absence of any temperature measuring device. A pyrometer in the hands of a novice cannot take the place of an experienced melter, for even with the best of care pyrometer installations have the habit of getting out

of order just at the time they are most needed. But if in the hands of an experienced melter, a loose connection or a partially burnt out weld, causing a reading a hundred or more degrees low, is quickly detected and the difficulty remedied. The writer has known of a gray iron molder heating aluminum to 1700 degrees Fahr. merely because the pyrometer failed to reach the 1300 mark that he was instructed to carry it to.

Also, no amount of work in the chemical, physical testing, or metallographic laboratory can replace watchful care and knowledge wrought of long experience in the foundry, but the laboratory work can be made of such great assistance in meeting the difficult problems of the foundry as to much more than pay for itself on a dollars and cents basis, besides being an absolute essential in meeting the exacting requirements of the Air Service.

Fuels and Furnaces for Melting Copper and Brass Alloys

By T. H. A. Eastick*

In these days when cost cutting should be among the activities of the industrial executive, the vital nature of the problem of proper selection of fuel and furnace becomes apparent. The selection of the right equipment may mean the difference between profit and loss, and thus it behooves foundrymen and metal melters to devote as much study as is possible to the question.

Treatment of the subject involves far more than a mere discussion of the characteristics of different fuels and the design and construction of different furnace types; the manufacturing economy of the problem must be considered as well as many other factors which are of importance.

For instance, the metallurgical features, to mention only one of many groups of factors of the problem, are too often neglected. Frequently the mechanical engineer alone is allowed to make the selection and direct the installation and operation.

Before discussing the various aspects of this important matter it might be well, perhaps, to state a few generalizations and anxioms which have been found to possess value in enabling one to obtain a broad comprehensive grasp of problems in heating and the selection and use of furnaces and fuel for heating work.

There should be a broader recognition of the fact that owing to greatly varying conditions met with there can be no universally "best furnace" or "best fuel" for melting nonferrous metals. The "best" equipment for this purpose is, in most cases, a compromise between conflicting characteristics of furnace types and designs and fuels. Arriving at such a compromise is a process

*Died at Montreal, March 7, 1922.

requiring considerable judgment and experience in industrial furnace engineering and metallurgy.

It is a common, though none the less illogical, practice to compare two different types and designs of furnaces using different fuels, and attributing the difference between them to the fuel, where as a matter of fact the differences due to the fuel are in most cases negligible. For instance, frequent comparisons are made between electric furnaces and oil or coal furnaces. Such a comparison is meaningless and entirely misleading. The terms "electric furnaces" and "fuel furnaces," etc., are, in the first place, entirely too ambiguous. Granted that what is intended is a comparison, for instance, between a tilting oil fired crucible furnace and an electric carbon resistance reverberatory furnace, a moment's real reflection will show that the difference between these furnaces is not due to the fact that the one is heated by electricity and the other by oil, but is due primarily to fundamental difference of type and design.

Possibilities in Reducing Fuel Losses

It has been found that economies result from a study of all the industrial heating operations in a plant as a whole before studying each industrial operation. There are many plants where steam coal is burned under boilers, anthracite coal in the casting shop or foundry, fuel oil in annealing furnaces and coal gas in core ovens and hardening furnaces. A broad comprehensive study of the fuel and furnace conditions in such a plant would unquestionably reveal where remarkable savings could be effected.

An original and useful conception of the economic value of different fuels has been published recently by Gilbert and Pogue, and as it has an important bearing on all problems dealing with fuels and heating equipment, it seems desirable to briefly summarize the main features.

The value of a fuel has in the past been estimated on the basis of its heat content per unit of quantity (Steam coal= 14,000 B.t.u per pound; fuel oil=19,000 B.t.u. per pound; electricity=3411 B.t.u. per kilowatt-hour; city gas=600 B.t.u. per cubic foot; etc.) and its price per unit quantity.

However, there has always been a sort of tacit understanding that other considerations enter into the question and that the proper fuel for a given purpose is not necessarily the cheapest per unit of quantity or the greatest in heat unit content. It is now realized that besides the price and heat value, the physical form in which the fuel occurs is of the greatest importance.

From this fact, the term "form value" is derived, and is used to indicate the value of a fuel as affected by its physical or chemical form. Obviously gas and electricity, for example, each has a high form value; they can be handled, transported, and burned with a minimum of labor as compared with coal or wood. In many cases, in fact, for the foundryman in most cases, the "form value" of the fuels under consideration is of greater importance than either the price or the heat value.

Having now stated briefly some of the more important principles of this subject, the manner of their application should be of interest.

The types of furnace which have demonstrated their usefulness in different fields and which may therefore be considered available for melting copper and brass alloys are:

1. Stationary and tilting electric or open flame reverberatory furnaces.
2. Stationary and tilting crucible furnaces.
3. Electric induction furnaces.

The selection of the general type of furnace should be governed by such considerations as follows:

1. Average weight of castings to be produced, which, to a large extent, decides the capacity of the furnace desired. Obviously a furnace of great capacity is not suited, under ordinary conditions, to the production of very small castings; neither is a crucible furnace suitable for very large ones.
2. The chemical and metallurgical characteristics of the metals to be melted. High zinc mixtures are difficult to handle in "open flame" and in some types of electric reverberatory furnaces; high lead and tin mixtures are difficult to handle in furnaces which do not permit thorough stirring.

3. Diversity of product. If the requirements call for the continuous production of one or two standard alloys, the general type of furnace suitable would be different from that suitable for production of a great number of different alloys. A brass foundry in a large automobile factory making a standard line of phosphor bronze bushings, from perhaps, ingot metals, could well consider a large capacity tilting reverberatory furnace, whereas the small jobbing brass foundry should carefully study the possibilities of a tilting crucible furnace.
4. Manufacturing economics. Initial investment, interest, depreciation, and the relation of these to the expected operating load factor of the plant, the "degree of versatility" or adaptability of the installation to the production of different products, and the overhead charges of the installation should business conditions require a shut down, etc. are matters of what might be termed "manufacturing economics." These have a most important bearing on the selection of equipment.

Such considerations are especially of great importance in the case of electric equipment on account of the high initial investment required and the liabilities assumed through necessary power contracts, etc. In general it may be stated that the larger the unit or charge melted, the lower the cost per pound. The larger the charge the lower the degree of versatility and the more important the "load factor" becomes. A balance must be struck between the cost of melting, the degree of versatility necessary as governed by the nature of the business, and the importance of the load factor which is to some extent governed by the initial cost of the installation.

It is worth remembering also, in connection with this phase of the problem, that any piece of equipment in a plant is only returning on the investment when it is in operation, and also that a large capacity furnace containing metal to be poured represents a loss as long as it is not melting metal to capacity.

The selection and use of furnaces or fuels or electricity should be based upon a consideration of all the factors relating to manufacturing requirements and plant conditions, which influence the quality and cost of the finished castings.

Discussion—Selection of Fuels and Furnaces for Melting Copper and Brass Alloys

CHAIRMAN J. L. JONES.—There seems to have been a sort of a reversion of feeling in regard to electric furnaces recently, in some quarters at least, for a while the electric furnace was considered the most up-to-date and most satisfactory method of melting, but recently quite a few people that are using the electric furnaces have lost their enthusiasm to a certain extent. Now probably this is for good and sufficient reason. Perhaps the crucible people are offering inducements to users to go back to crucibles.

N. K. B. PATCH: I don't know that I have very much to say except that we have tried the electric furnace with a great deal of satisfaction. We do not believe, however, that the electric furnace is a panacea for all the foundry ills, and we are also pretty well convinced that there are types of melting that are just as well done in the fuel fired furnace, and vice versa. In other words, there are places where you can apply the electric furnace with satisfaction and there are other places where the fuel fired furnace will give equal satisfaction. We have pretty well concluded that any melting proposition is one of a combination of fuel, furnace and brains, and if there isn't enough brains put into the job, why it doesn't make much difference what tool you are using in the way of melting equipment as to what your product may be. If you have a sufficient amount of brains applied to the melting practice, almost any tool, no matter how crude, will quite probably give a satisfactory product. The melting rate, of course, is generally the thing that the furnace manufacturer will claim is advantageous. In certain alloys there is no question but what the electric furnaces have a marked advantage over other furnaces for that purpose. The application of the open-flame furnace to any certain class of melting is, however, just as good from the standpoint of melting

rate as some of the electric furnaces are, if there is a sufficient amount of attention paid to both control of the furnace, atmosphere and the temperature and all the other variations that go into making a success or a failure. I don't think that a foundryman who is considering the purchase of a furnace should jump to a conclusion without a good deal of thought as to what furnace he should use. Just because the electric furnace has at least a certain amount of prominence, there is no excuse in taking immediate action on buying it. It seems to me that one considering the purchase of a furnace would first consider all the conditions that are connected with it so that he can decide as to whether the first cost is going to be the most vital question or whether the melting ratio is going to be the more vital question, or whether the class of help he has available is the character that will enable him to use one type of furnace or another with better or worse results. I think that we are all convinced that the furnace question is one which is open to so much abuse by the improper men using it, improper handling, improper labor supply, and so on, that claims which have been made for the success or failure for any given furnace should be taken with a grain of salt, or at least a certain amount of investigation should be made to find out all the conditions under which that furnace did give the results claimed for it.

CHAIRMAN J. L. JONES: I once had the pleasure of hearing Mr. Marconi speak, or lecture rather, and he had a number of very interesting experiments, and he was very anxious not to disappoint his audience. He told us he had gone to the trouble to have three different sources of supply of current available that night; and it was fortunate he did so, because two of those supplies failed. He tried first one and that failed, and then he tried another and that failed, but the third one was available, and I think something like this should be in the mind of the foundryman when he puts in his furnace. It is desirable to have varied equipment. If there should be a strike and you could not get coal or coke and have electricity available, it might be a very good thing for you; it might be money in your pocket.

I think this should be borne in mind in selecting a furnace, as one thing at least.

Producing Two-Part Castings in Three-Part Molds

By WILLIAM H. PARRY, Brooklyn, N. Y.

On first thought advocating the use of three-part flasks in making castings usually molded in two-part flasks would appear an absurd proposition. However, there are conditions surrounding the rapid production of sound castings for pressure work which tax the ingenuity of the most expert foundrymen, and in the opinion of the writer, many of the difficulties can be removed by employing the three-part mold.

In these days of the almost universal use of production pattern-plates, it is not unusual to find that such plates do not always produce as many good castings as the number of patterns on them would indicate; in fact, in many instances not one good casting has been found among the great number cast.

It is not claimed that improper gating is the cause of these failures in all cases, but there is no question but what it is a contributing factor in a large percentage of lost castings.

In designing production pattern plates it is not always a good policy to crowd as many patterns into the confines of the flask spaces as possible, with the idea of increasing production, because frequently the result is exactly the reverse of

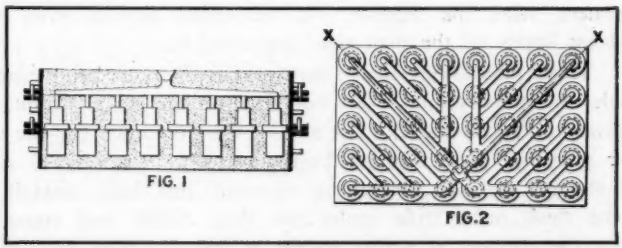


FIG. 1—SECTION OF THREE-PART MOLD ASSEMBLED. THE SECTION IS ON THE LINE *XX*, FIG. 2. FIG. 2—PLAN VIEW SHOWING ARRANGEMENT OF PATTERNS AND RUNNERS

what was intended. The number of plate patterns is restricted to the spaces not occupied by the runners and necessary connecting gates.

Makes Mold in Three Parts

Fig. 1 illustrates a staggered section of a three-part mold assembled, showing the sprue and runner in the cope, the pop gates and the upper part of the castings in the cheek, and the lower part of the castings in the drag. Fig. 2 shows the position and number of patterns on the plate or plates and the arrangement of the runners and gates. Fig. 1 is a section of Fig. 2 on the lines *x-x*.

It will be noted that this is an apparently simple two-part job. At first, the work was planned for a two-part mold with gates attached to the flanges and two runners running lengthwise. The castings were to stand a hydrostatic pressure of 1000 pounds per square inch after being finished all over, and hundreds of thousands of them were needed badly. However, every casting produced in this manner was porous and therefore it was evident that some other method of gating must be tried.

Pattern plates were made by the dozen each embodying some new method, but they all failed. Finally, a mechanic not connected with the foundry force, suggested the "three-high" idea. When he tried to explain how a two-part job could be better made in "three boxes" of sand, he was considered insane; nevertheless in desperation the foundry management tried his scheme. It succeeded beyond even the wildest hopes of the man who suggested it.

Three plates were made, the one for the cope being rigged with the runners and about one half of the sprue height, as shown at Figs. 1 and 2. The cheek plate accounted for the upper parts of the castings. Pop gates were attached to each of the 40 patterns, projecting upwards just high enough to come flush or a trifle under the flask height and engaging with the runners at points shown at Fig. 2. The drag plate was mounted with the larger of the two hubs. The sprue was so placed that the inrushing metal did not pour directly

into one casting cavity, while the runners were designed to give the most direct passage to the metal.

Poured Forty Castings Per Mold

As tight flasks were used, it was possible to pour 40 sound castings to each mold. This was 17 in excess of the number of patterns spaced on the two-part flask plates as originally designed, and from which not one casting free from porosity was obtained.

One decided advantage in using the elevated runner method is that no attention need be paid to the runner or gate positions in placing and spacing the patterns other than to keep in mind that they must not be staggered so that the runner shape departs from easy flowing lines. However, a fair variation from a straight line is allowable. Again, this method lends itself to direct pouring into the casting cavities and provides feeders to counteract gravity shrinkage in castings with heavy and deep sections on each side of a light flange.

On the original two-part flask plates the gates engaged with the flange so that the metal first flowed down then up in the cope. The upper hubs did not always fill, and when they did, sponginess was to be found at the junction of hub and flange.

In Fig. 3, *A*, *B*, *C* and *D* show four quarter layouts of a similar piece on split pattern plates, half on each side. The illustration indicates that many patterns can be placed on

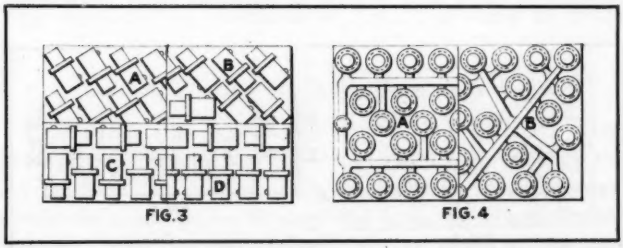


FIG. 3 FIG. 4

FIG. 3—FOUR QUARTER LAYOUTS SHOWING ARRANGEMENT WHEN SPLIT PATTERN PLATES WERE USED. FIG. 4—TWO HALF LAYOUTS SHOWING CONVENTIONAL GATES AND RUNNERS

plates without any attention being paid to gates and runners, as they would be provided for in the cope of a three-high mold. If the layouts as at *A*, *C* and *D*, Fig. 3, are followed, 28 castings are possible, while if *B* is employed 26 can be obtained. This is at least eight in excess of what could be expected from the two-part flask method.

This well repays the extra labor of ramming up a shallow cope to form the overhead runner. Pop gates are not shown on these layouts, though they can be placed on either hubs or flanges, their position at times being determined by the ease with which they can be separated from the castings or located so that the following machining operations will remove all evidence of their presence.

In Fig. 4 the two half layouts *A* and *B* show the antiquated runners and gates usually employed to coax the metal into a two-part flask mold in an attempt to get sound castings. Layout *A* provides for a barely possible maximum of 33 castings with a chance of losing one-third of them, while layout *B* can be crowded to account for 29 with a fair chance for a 25 per cent loss. The estimated loss percentages are in favor of layout *B*, because of the shorter run of the metal and the likelihood that some of the cavities in layout *A* will be filled with air only.

Fig. 5 is a layout of midway gating to the flanges, the metal being fed from the top runners located in the cheek and through uprights shown in section at Fig. 6. No great advantage in using this method is apparent other than that it

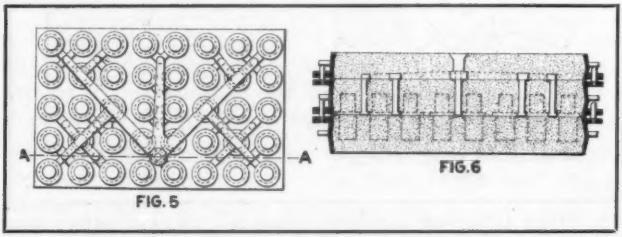


FIG. 5—MIDWAY GATING TO THE FLANGES. FIG. 6—A SECTION THROUGH *AA*, FIG. 5

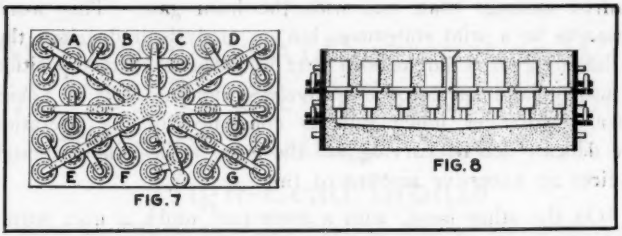


FIG. 7

FIG. 8

FIG. 7—AN ARRANGEMENT BY WHICH MUCH SPACE IS LOST AT *A, B, C,* ETC., DESPITE CROWDING AT OTHER POINTS.
FIG. 8—HOW BOTTOM POURING CAN BE EMPLOYED WITHOUT HORN GATES

may prove convenient on work that must be poured into the midsection of the casting.

Fig. 6 is a section of Fig. 5 at *AA* and illustrates the possibility of feeding 40 castings with only 16 upright feeders. This arrangement is of rather dubious advantage, but it can be adapted to some classes of work. Fig. 7 serves to illustrate how bad a runner layout can be to offset the virtues claimed here for overhead or bottom pouring.

It will be noted that 41 castings are expected from this plate. This number is obtained by crowding as many patterns as possible within a prescribed space, regardless of future consequences. Nevertheless, with all the crowding, there are seven waste spaces—*A, B, C, D, E, F* and *G*—which could be utilized as in Fig. 2, where the runners are laid out so that a mass of metal will not form at the sprue position as in Fig. 7. This condition, as illustrated in Fig. 7, is likely to create serious trouble when cooling.

Bottom Pouring Without Horn Gates

Fig. 8 shows how bottom pouring is made effective without horn gates. Bottom pouring is no more expensive than the ordinary method and is successfully employed on pressure work. Note how the sprue passes through the cope and cheek feeding the runners, gates and 40 castings just as easily as the old-fashioned horn gate fed one casting. As a matter of fact, it is easier by this bottom pouring scheme to make 40 or even a

hundred castings than one with the horn gate. This would appear to be a wild statement, but on analysis it develops that the handling of a single horn gate to place in correct position, or near it, and keep it there, involves molding skill of a high order. Moreover much time is consumed in the operation. The delicate job of curving out the gate, while simple enough, requires an excessive amount of time.

On the other hand, with a three-part mold, a man with a machine, proper flask equipment, and good pattern plates can ram up two or three complete molds (40 castings to a mold) and can pour them off before the man using the horn gate method closes down his one mold containing a single casting.

In giving publicity to a scheme that involves the ramming of an extra flask, be it ever so shallow, to pour castings that are usually made or spoiled in two-part flasks the writer is not unmindful of the doubt that will be expressed by many readers Nevertheless, in spite of the extra labor and the expense of increased flask equipment, this method will succeed in making sound castings at less cost than any other known method. It will be noted that no mention is made as to the use of risers as part of any of the three proposed methods, as that is left to the individual tastes. A closer study of the bottom pouring system, as shown in Fig. 8, would indicate that risers taken off each casting would insure better work.

Another objection that may make some foundrymen hesitate before adopting this method is the extra labor entailed in separating the castings from the gates. A little study discloses the simple solution, which is to first cut through the runners, lay the castings on their sides, and cut through the gates. This method applies to nonferrous castings, in most cases when gray iron is used the castings can be knocked off.

It is but fair to state that snap molds cannot be expected to give results comparable with those of tight flask molds. The binding qualities of stiff metal flasks permit the placing of more patterns on a plate with a greater factor of pressure resisting safety, than would be possible with snap molds even when pouring jackets are used.

An Investigation of Segregation With A View To Preventing Its Occurrence in Castings Made Of High-Lead Bronze

RICHARD EDWIN LEE AND FRED B. TRACE, Meadville, Pa.

One of the most perplexing problems attendant upon the manufacture of metal castings is the prevention of the occurrence of segregation in the finished product. These segregations are not to be confused with either the so-called mechanical suspensions and enclosures of impurities or gas pockets. By the term segregation reference is made to the loose spongy structure which probably results from the separation of solid phases within the casting.

In many instances the effects of segregation are so marked that the casting must be rejected. In some foundries the loss from this source amounts to large sums during the year. It is quite obvious, therefore, that the solution of this problem is highly desirable.

In certain fields of metallurgy considerable progress has been made, whereas in others, little seems to have been achieved in formulating procedures whereby segregation may be prevented. In the manufacture of alloys, and in the production of castings, particularly those made from bronze and brass, the loss from rejections due to the presence of segregation has been extremely large.

It was to this latter field of investigation that the attention of the authors was directed.

About a year ago arrangements were completed whereby an investigation was to be undertaken with a view to formulating such procedures for foundry practice as would prevent the occurrence of segregations in castings of "high-lead" bronze.

This paper contains the report of this investigation.

Part of the work reported herein was done in the foundry

of the company* supporting the investigation. In this connection the authors would acknowledge their indebtedness to Alexander Turner, president of the company, and to J. R. Gill, the general manager. The "'breaking" tests were made in the Erie Railroad testing laboratories under the direction of R. B. Watson, engineer of tests. To his interest and courtesy we are indebted for this privilege.

Before entering upon the detailed report of the investigation it would seem wise to make a brief survey of the relationships involved.

I *Analysis of Problem*

The two factors which determine the condition of an alloy are its chemical composition and its physical structure (homogeneity). The difficulty in preparing an alloy for a given use so that it will meet the requirements of efficiency lies in the fact that said alloy can not be realized as a rule if but one of these factors is considered. Attention to chemical composition alone seldom enables the production of the desirable alloy, the element of plasticity or of hardness may be secured but at the expense of defective physical structure, perhaps; on the other hand homogeneity may be secured, for example by using a eutectic mixture, but its coefficient of friction may be too high.

The usual procedure in practice, therefore, is to sacrifice in part the desirable qualities of the one factor in order to gain certain contributions from the other factor, relying on the information at hand to control the processes in such a manner that the nature of the resulting alloy will approximate that of the ideal casting.

II *Theoretical Consideration Relative to the Prevention of Segregation*

Knowing that a casting made from an alloy having a chemical composition approximating 70 per cent of copper, 25 per cent of lead, and 5 per cent of tin is desirable providing a homogeneous physical structure is achieved, we shall regard the limits of chemical composition as established and direct our investigations with a view to ascertaining how the processes

*Bronze Metal Co., Meadville, Pa.

involved in the production of the casting may be controlled so as to prevent segregation.

From our study of the constitutional or equilibrium diagrams of various systems of molten metals the following conclusions from purely theoretical considerations seem obvious:

1. Effects of impurities. The examination of equilibrium diagrams of various systems of molten metals has shown that the type of diagram is largely dependent upon the nature and composition of the components materials and that an intelligent control of the processes occurring during the production of the alloy in the form of a casting is conditioned upon the recognition and understanding of the diagram representative of the processes whose control is being attempted. Therefore, an exact knowledge of the materials with reference to chemical individualities involved and percentages is prerequisite to the proper control in order to prevent segregation.

Additions to, or losses from the components, whether known or unknown, from any source whatever, if they alter the processes involved and their evaluation is neglected, should be regarded as impurities. Some of the common sources of error are: inaccurate chemical analysis, accidental introduction of foreign materials, volatilization, oxidation, occlusion of gases, etc. The use of fluxes can be traced to the effort to maintain the purity of components.

2. Effects of careless mixing. The effects of failure to thoroughly mix and bring into intimate contact the components of a system in the molten condition are so well known that comment here is unnecessary. It may be pointed out, however, that if large masses of a component are permitted to crystallize out in layers segregation are bound to occur.

Owing to the relative high viscosity of molten metal, the foundryman is warned against depending on the mixing effects due to convection currents and diffusion.

3. Thermal and cooling effects. Assuming that the components of a given system of molten metals have been thoroughly mixed and are free from impurities, the thermal behavior of metallic alloys with changing temperature is prob-

ably more closely related to the constitution of the solid alloy than any other property. In fact it is possible to predict in certain instances, the physical properties of any alloy by an inspection of its equilibrium diagram.

From a study of the theory of segregation it is observed that when the temperature of the molten alloy is progressively lowered that crystals of the components which have the highest freezing-point are the first to separate but remain submerged in the melt (mother-liquid), float to the top or sink to the bottom, where they grow by the process of diffusion as described. As the melt cools other components separate out in a similar manner; finally, when the eutectic point is reached the components of this mixture separate out slowly but simultaneously at a constant temperature forming a homogenous mass of small crystals.

It is obvious that an extremely high casting temperature* is conducive to the formation of large crystal skeletons as the period of growth in the mother-liquor is greatly prolonged and the process of diffusion is facilitated. This type of crystallization results in segregation which manifests itself in stratification and a loose type of structure owing to a hindrance of that which was designated previously as the filling-up process.

Conditioning that no new factors are introduced, a medium casting temperature should give, theoretically, a smaller-crystal-interlocking structure; and a low casting temperature, a small-crystal structure of fine-grain appearance. On the other hand if the metal is poured at a low casting temperature there is likely to be serious defects in the casting owing to an incomplete filling-up of the mold resulting in what are called cold shuts.

In the foregoing discussion, it has been assumed that the fused alloy was allowed to cool naturally. In foundry practice chill molds are sometimes used to increase the rate of cooling of the fused metal. These molds are usually made of metal. They conduct the heat away rapidly and the process of solidification is greatly hastened. In the case of iron it is found

*"Casting temperature" is used here to indicate the temperature at which the molten metal is poured into the mold.

almost universally that the metal from the same crucible poured in a chill mold yields a casting of far finer structure and better mechanical properties than the one made in a mold made of sand. The effects of chilling molten high-lead bronze in the producing of castings is made a part of the record of this investigation and is presented later in the paper.

Finally, unequal rates of cooling in different portions of a casting, resulting from shape of latter, are undoubtedly the cause of some segregation owing to localization of crystals.

Before taking up the section of the paper devoted to the experimental part of the work it may be pointed out that these theoretical considerations indicated the method of attacking the problem presented to the authors.

III *Outline of Method of Attack*

At the conclusion of the survey of the theoretical aspects of the problem it was apparent that there were at least four variables,—four factors, the influence of which ought to be ascertained if a solution of the problem was to be undertaken. In fact, several of the factors seemed to be so intimately related to the phenomenon of segregation that it was hoped that a careful inquiry into their effects might suggest the necessary control which would lead to the solution of the problem.

The four factors to which reference was made in the preceding paragraph are: (1), effects of impurities; (2), effects of careless mixing; (3), thermal and rate-of-cooling effects; (4), effects due to variation in percentages of components.

In this investigation, however, the specific object of which is the formulation of procedures which will prevent segregation in a bearing made from high-lead bronze, the fourth factor virtually becomes a constant as the limits imposed are that the casting shall carry 20 to 30 per cent of lead.

IV *General Procedure*

In conducting the experimental part of the investigation the following procedure was adhered to in general: The crucible was charged with a mixture of scrap metal, previously analyzed, and sufficient virgin metal then added to insure the production of an alloy whose chemical composition would meet

the specifications in that respect. The crucible was then heated to the desired temperature when the dross was skimmed off and sufficient phosphor-copper added to remove the oxides.

The molten metal was stirred or puddled from time to time, but with particular vigor during the introduction of the phosphor-copper, after which the molten metal was poured into sand molds and the casting allowed to cool naturally in the mold.

The molds were made from a pattern representing the common type of 5½ inches x 10 inches journal bearing, used by many railroads at the present time.

After the castings had been allowed to cool they were shaken out of the mold, cleaned, rough edges removed by means of an emery-wheel, taken to the machine-shop and finally bored to meet the specifications in regard to dimensions. The castings were regarded then as being ready for the various tests to which they were later subjected.

In order to obtain required data in regard to certain physical properties of the castings they were taken to the Erie Railroad testing laboratories where they were broken under the direction of the engineer of tests. The castings were broken by means of a testing machine and the total breaking-load recorded. From this data now at hand it was possible to calculate the modulus of rupture for each casting. The fracture was closely examined and a record made with respect to appearance, structure, and homogeneity of the material, size, color, and locations of any segregations.

Several holes were then drilled in three different sections at regular intervals along the face of the fracture, and a complete chemical analysis made of the drillings from each section. If the fracture showed the presence of a segregation, drillings were taken from the segregated section and from the good sections on either side of it and analyzed separately. Complete records of the tests and observations of each casting are incorporated in the complete report.

Any deviations from the procedures as outlined are indicated in the record and history of tests for each casting.

V. *Experimental*

Series 1

Series 1 consisted of preliminary tests to determine the effect of removal of impurities and thorough mechanical mixing of components in preventing segregation. From these preliminary tests it was concluded that the control of these factors was not sufficient to insure castings free from segregation.

Series 2

Series 2 consisted of preliminary tests on castings Nos. 1, 2, 3, 4 and 5 to determine variation in composition of segregated portions from that of the good portions of the casting.

The preliminary experimental work in this series was undertaken in the effort to ascertain if the chemical composition of the segregated portions of the castings varied greatly from that of the non-segregated portions; and if so, to determine which element or elements varied most.

Five different castings produced by usual foundry procedure and three different classes of bearings were chosen at random. Drillings were taken from both the segregated and non-segregated portions as indicated in "General Procedure" and subjected to examination. The record of these tests follow:

Summary of Data on Castings Nos. 1 *to* 5

	Chemical Analysis			
Casting No.	Copper	Tin	Lead	
1. Good Section	65.43	5.38	28.29	
Segregation	65.66	3.61		29.83
2. Good Section	64.49	5.58	28.22	
Segregation	61.63	3.93		30.88
3. Good Section	69.13	5.58	23.45	
Segregation	69.56	4.59		24.34
4. Good Section	72.12	6.15	20.25	
Segregation	74.11	4.41		20.32
5. Good Section	72.43	5.79	20.58	
Segregation	78.21	4.07		17.06
Average of:				
Good Sections	68.72	5.69	24.16	
Segregation	69.83	4.12		24.49
Difference	+1.11	— 1.57	+ .33	
Per cent of variation	+1.61	—27.59	+1.34	

Discussion and Conclusions. Castings Nos. 1 *to* 5

An examination of the history and record of the tests as prepared from this series of experiments will show:

(1) That all of the five castings exhibited segregations, which were most frequently described as being of fine grain and of copper color.

(2) That if the average composition of the drillings from the non-segregated portions of the castings be compared with that of the drillings from the segregated portions it will be seen that the former contain 1.11 per cent more of copper, 1.57 per cent less of tin, and .33 per cent more of lead, than the latter.

If these variations expressed in percentage composition be stated in terms of percentage of the component element then the average variation for tin is 27.59 per cent and less than 2 per cent for either lead or copper.

The most obvious conclusions to be drawn from the data obtained by these experiments and confirmed by later experiments are: (1) that in the redistribution of the components by segregation the segregated portions always contain a smaller percentage of tin than the non-segregated portions; and (2), that the percentage change of any element is always the greatest in the case of this component.

Series 3

Series 3 composed a study of thermal effects on castings Nos. 6 to 29 containing 20 per cent lead to determine the effects of heating the melts to various temperatures and allowing them to cool naturally in the molds.

The systematic study of the problems was now inaugurated; and inasmuch as the conclusions derived from purely theoretical considerations indicated that the physical properties of an alloy were very intimately related to its thermal treatment, it was thought best to take up this phase of the problem at the beginning of the investigation.

The study of the thermal treatment involves, however, the consideration of two factors; (1) the temperature to which the melt is subjected, and (2) the duration of heat effects or as it is expressed in this paper, the rate-of-cooling effects.

In the following series of experiments castings Nos. 6, 7, 8 and 9 were made from a charge heated to approximately 2000 degrees Fahr.; castings, Nos. 10, 11, 12 and 13 were made from a charge heated to 1800 degrees Fahr.; castings, Nos. 14, 15, 16, and 17 were made from a charge heated to 1600 degrees Fahr.; castings, Nos. 18, 19, 20, and 21 were made from a charge heated to 1400 degrees Fahr. The metal was melted in furnaces, heated by oil-burners having a capacity of about one ton.

Duplicate tests on effects of variation of temperature to which melts were heated are reported under history and record of tests for castings Nos. 22 to 29 which were prepared from charges melted in crucibles heated in a coke-pit.

The charges were graduated so that the alloy would contain approximately 20 per cent of lead. The melt was poured into the molds at the respective temperatures and allowed to cool naturally. The only variable introduced in this series of experiments was the temperature factor and it was evaluated at all times. See tables on pages 520 and 521.

Tests Designed to Check Data Obtained from Tests of Castings Nos. 6 to 21

Castings Nos. 22 to 25 were prepared from fragments of broken castings Nos. 6 to 21, and were melted in crucibles heated in a coke pit. The use of this type of crucible facilitated the control of the various processes. The charge for castings 22 and 23 was heated to 2150 degrees Fahr., cooled in the crucible to 2050 degrees Fahr. and then poured into the mold. The charge for castings 24 and 25 was heated to 2000 degrees Fahr. and poured into the mold at that temperature.

Summary and Conclusions of Data for Castings Nos. 6 to 29

The results obtained from this series of experiments may be summarized as follows:

1. Sixteen castings, Nos. 6 to 21, were made from charges graduated to contain approximately 75 per cent of

Summary of Data on Castings Nos. 6, 7, 8 *and* 9

Thermal Conditions. The charge was heated to 2050 degrees Fahr. and poured at that temperature. There was no segregation in these castings.

Physical Properties

Casting No.	Area of Cr.Sec. sq. in.	Breaking Load Total	Breaking Load, per sq. inch Cross Section	Modulus of Rupture
6	8.721	36,680 lbs.	4,201 lbs.	35,720 lbs
7	7.769	29,890 lbs.	3,847 lbs.	36,910 lbs
8	8.327	33,380 lbs.	4,010 lbs.	35,760 lbs
9	8.251	31,240 lbs.	3,786 lbs.	34,160 lbs
Av.	8.270	32,800 lbs.	3,961 lbs.	35,640 lbs

Chemical Analysis

Casting No.	Copper	Tin	Lead	Total
6	72.03	5.63	21.21	98.89
7	72.89	5.61	21.34	99.34
8	72.03	5.51	21.36	98.90
9	72.05	5.56	21.15	98.76
Average	72.26	5.58	21.27	99.11

Summary of Data on Castings Nos. 10, 11, 12 *and* 13

Thermal Conditions: The charge was heated to 1800 degrees Fahr. and poured at that temperature. All castings contained segregations.

Physical Properties

Casting No.	Area of Cr. Sec. sq. in.	Breaking Load Total	Breaking Load, per sq. inch Cross Section	Modulus of Rupture
10	7.961	29,000 lbs.	3,643 lbs.	34,080 lbs
11	8.078	29,860 lbs.	3,692 lbs.	33,890 lbs
12	8.616	32,660 lbs.	3,791 lbs.	32,620 lbs
13	8.260	32,330 lbs.	3,914 lbs.	35,240 lbs
Av.	8.229	30,960 lbs.	3,760 lbs.	33,960 lbs

Chemical Analysis

Casting No.	Copper	Tin	Lead
10. Good Section	75.05	5.52	18.19
Segregation	76.64	4.48	17.70
11. Good Section	75.65	5.67	18.33
Segregation	77.17	5.00	17.78
12. Good Section	74.06	5.63	18.40
Segregation	77.63	4.42	17.40
13. Good Section	74.81	5.48	18.37
Segregation	77.00	4.24	16.61
Average of:			
Good Sections	74.89	5.57	18.26
Segregation	77.11	4.54	17.37
Difference	+2.22	— 1.03	— .89
Per cent of variation	+2.96	—18.50	—4.80

Summary of Data on Castings Nos. 14, 15, 16 *and* 17

Thermal Conditions: The charge was heated to 1600 degrees Fahr. and poured at that temperature. All castings contained segregations.

Casting No.	Area of Cr. Sec. sq. in.	Breaking Load Total	Breaking Load lbs. per sq. inch Cross Section	Modulus of Rupture
14	8.472	34,460 lbs.	4,069 lbs.	35,620 lbs
15	8.491	35,150 lbs.	4,139 lbs.	36,210 lbs
16	8.395	30,520 lbs.	3,635 lbs.	32,160 lbs
17	8.395	31,720 lbs.	3,778 lbs.	33,430 lbs
Av.	8.438	32,963 lbs.	3,905 lbs.	34,353 lbs

	Chemical Analysis			
Casting No.	Copper	Tin	Lead	
14. Good Section	74.54	5.79	18.10	
Segregation	76.60	4.32		16.78
15. Good Section	74.54	5.48	18.23	
Segregation	77.41	3.81		16.62
16. Good Section	74.89	5.40	18.14	
Segregation	76.70	4.17		17.15
17. Good Section	74.93	5.77	18.28	
Segregation	78.26	4.09		15.88
Average of:				
Good Sections	74.83	5.61	18.19	
Segregations	77.24	4.10		16.61
Difference	+2.41	— 1.51	—1.58	
Per cent of variation	+3.20	—26.90	—8.70	

Summary of Data on Castings Nos. 18, 19, 20 *and* 21

Thermal Conditions. The charge was heated to 1400 degrees Fahr. and poured at that temperature. Castings contained segregations.

Casting No.	Area of Cr. Sec. sq. in.	Breaking Load Total	Breaking Load lbs. per sq. inch Cross Section	Modulus of Rupture
18	8.106	29,780 lbs.	3,674 lbs.	33,650 lbs
19	8.510	33,600 lbs.	3,948 lbs.	34,440 lbs
20	8.269	29,940 lbs.	3,621 lbs.	32,600 lbs
21	7.961	30,610 lbs.	3,845 lbs.	35,970 lbs
Av.	8.212	30,983 lbs.	3,772 lbs.	34,164 lbs

Casting No.	Copper	Tin	Lead	
18. Good Section	73.20	5.92	19.82	
Segregation	75.32	4.53		19.23
19. Good Section	74.09	6.01	19.83	
Segregation	76.01	4.34		19.43
20. Good Section	73.00	5.86	19.64	
Segregation	74.19	4.45		19.92
21. Good Section	73.71	5.95	19.60	
Segregation	74.04	4.03		20.19
Average of:				
Good Sections	73.50	5.95	19.72	
Segregations	74.89	4.09		19.89
Difference	+1.39	— 1.86	— .03	
Per cent of variation	+1.90	—31.20	—. 15	

copper, 5 per cent of tin, and 20 per cent of lead. Four charges were prepared and four castings were made from each charge. The first charge was heated to and the melt poured at approximately 2000; the second charge, at 1800; the third at 1600; and the fourth at 1400 degrees Fahr. In all cases the alloy was allowed to cool naturally.

All of the castings except those poured at 2000 degrees Fahr. exhibited segregations. Those poured at this temperature were found to have not only approximately the same composition but also a very homogeneous structure of practically uniform chemical composition.

2. The average of the results secured by analysis of drillings taken from the castings containing segregation showed the good portions of the casting to be of uniform composition but, without exception, to have a smaller percentage of tin. Relative to the amount present, this component showed the highest percentage of variation. Furthermore, it should be noted that this deviation increased as the temperature of the pouring was lowered. These results are in accord with those obtained in series 2.

3. The structure of the segregations in the castings made from charges heated to the lower temperatures indicated that the filling-up process discussed previously had been greatly hindered by the higher viscosity of the alloy at the lower temperatures. Furthermore, many of these castings contained gas-pockets.

4. The average modulus of rupture for castings free from segregations was 35,500 pounds; and for those showing segregations, 34,000 pounds. Casting No. 29 poured at 1600 degrees Fahr. gave a modulus of only 26,280 pounds.

5. Check tests on castings Nos. 22 to 29, made from fragments of broken castings Nos. 6 to 21, and melted in a crucible heated in a coke-pit confirmed data with reference to effects of variation in temperature at which the charge is melted and poured.

It may be noted here that no check tests are offered for castings poured at 1400 degrees Fahr. This is due to the fact

that the practice in the foundry was altered as the investigation proceeded with the result that the gates on the molds were made smaller. Pouring at relatively low temperatures was thereby rendered impracticable.

Conclusion—The results of this series of experiments point to but one conclusion, namely,—that if the charge is not heated to a temperature above 1800 degrees Fahr., the castings of specified composition will contain segregations. This assumes of course that the general procedure as described is not otherwise modified.

Series 4

Series 4 was run to determine the effects of cooling the melt at various rates. Castings Nos. 30 to 37 containing 20 per cent lead composed the series. It seems logical to inquire whether the satisfactory results obtained by the use of relative high temperatures as shown by the tests in series 2 are to be attributed to this factor or to the latter factor. The general theory of the influence of the second factor being, as has been pointed out previously, that if the molten alloy is heated to a high temperature and poured at once into the molds the metal remains in the liquid state for a relatively long period of time. Such a condition is favorable to the development of large crystals and their distribution in layers which results in coarse or loose structure in the casting. On the other hand, if the melt is cooled too rapidly, crystal formation is greatly disturbed if not practically inhibited and the casting exhibits a granular structure. The results sought for are to be found, apparently, in rate-of-cooling processes which have not been too greatly increased or too sharply retarded.

The following series of experiments were outlined, therefore, in the effort to ascertain the effect of controlling this latter factor within certain known limits.

The same general procedure as outlined was followed in the production of the castings (Nos. 30 to 37) used for this series of tests. It is to be noted, however, that the molten alloy was heated to specified temperatures and then cooled (chilled) rapidly to lower temperatures before pouring it in

each case. This chilling process, that is, the increasing of the rate-of-cooling of the melt, was accomplished by the introduction of borings of the same composition as the molten alloy. All temperatures are recorded in the history and record of tests for each casting. See tables on page 525.

Summary and Conclusions of Data of Castings Nos. 30 to 37

The history and record of tests undertaken to determine the effects of cooling the molten alloy at various rates with reference to the prevention of the occurrence of segregation may be briefly formulated as follows:

1. Eight castings, Nos. 30 to 37, were made by the usual procedure, except that the molten alloy was chilled before pouring.

Castings Nos. 30 and 31 were made from a charge heated to 2000 and chilled to 1800 degrees Fahr.; and castings Nos. 32, 33, 34, 35, 36, and 37 from a charge heated to 1800 and chilled to 1600 degrees Fahr. The metal was poured at the temperature to which it was chilled, and then allowed to cool naturally.

All of the castings made from the charge heated to 2000 and chilled to 1800 degrees Fahr. were free from segregations, while only two out of the six castings made from a melt heated to 1800 degrees Fahr. and cooled to 1600, were found to be entirely free from this defect.

2. The chemical analysis of the drillings taken from the castings containing segregations showed the same general variation in composition with respect to tin that was shown in Series 2 and 3.

3. The average modulus for castings made at the higher temperature was 40,000 pounds; for the two good castings in the lot made at the lower temperature, 36,000 pounds; and for the castings exhibiting segregations, 32,000 pounds.

4. In general, the castings in this series possessed a structure of finer grain than those in the preceding series which had been heated to a corresponding temperature.

Conclusion. The results of this series of experiments point to practically the same conclusion as that indicated by series

Summary of Data on Two Preceding Castings No. 30 and 31

Thermal Conditions: The charge was heated to 2000 degrees Fahr., chilled with borings to 1800 degrees Fahr. and poured at that temperature. There were no segregations in these castings.

Physical Properties

Casting No.	Area of Cr. Sec. sq. in.	Breaking Load Total	Breaking Load, per sq. inch Cross Section	Modulus of Rupture
30	8.298	36,850 lbs.	4,440 lbs.	39,800 lbs
31	8.395	39,420 lbs.	4,720 lbs.	41,540 lbs
Av.	8.357	38,135 lbs.	4,580 lbs.	40,670 lbs

Chemical Analysis

Casting No.	Copper	Tin	Lead	Total
30	75.84	4.42	19.00	99.26
31	75.81	4.52	19.11	99.44
Average	75.83	4.47	19.06	99.36

Summary of Data on Castings Nos. 32 to 37

Thermal Conditions: The charge was heated to 1800 degrees Fahr., chilled with borings to 1600 degrees Fahr. and poured at that temperature. Three of the castings in this lot showed segregations. One casting, though showing no segregation of metal, was rejected because of its lack of homogeneity in structure. The other two castings passed inspection.

Physical Properties

Casting No.	Area of Cr. Sec. sq. in.	Breaking Load Total	Breaking Load, per sq. inch Cross Section	Modulus of Rupture
32	8.635	25,000 lbs.	2,895 lbs.	23,906 lbs
33	8.395	35,840 lbs.	4,270 lbs.	37,770 lbs
34	8.443	33,720 lbs.	3,994 lbs.	35,150 lbs
Av.*	8.491	31,520 lbs.	3,720 lbs.	32,275 lbs
35	8.414	34,490 lbs.	4,099 lbs.	36,220 lbs
36	8.327	33,760 lbs.	4,054 lbs.	36,170 lbs
Av.**	8.371	34,125 lbs.	4,077 lbs.	36,195 lbs

**This is an average of the two castings which passed inspection.

*This is the average of the three castings showing segregations of the metal.

Casting No. 37: No data is presented as it contained no segregations but failed to pass inspection owing to lack of homogeneity of metal.

3,- namely, that if the charge is not heated and poured at a temperature above 1800 degrees Fahr., many of the castings made from it will contain segregations.

It is significant, however, that the castings made from a melt heated to 2000 degrees Fahr. and chilled to 1800 degrees Fahr. before pouring should have a modulus of 40,000 pounds, while those in series 2 poured at the higher temperature and

allowed to cool naturally showed a modulus of 35,500 pounds. This, in all probability, may be attributed to a better type of crystal formation and arrangement. This, at least, is the conclusion indicated by theoretical considerations.

Series 5

Series 5 was run to determine the effects of increasing the percentage of lead in the alloy. Castings Nos. 38 to 48 with a lead content of 26 per cent composed the series.

In the statement of the problem as originally presented to the author, the desirability of producing a high-lead bronze was emphasized. In all of the experiments described, hereto, an alloy containing approximately 20 per cent of lead has been used. Having ascertained how castings free from segregations can be made from a bronze of this composition, it now becomes necessary to determine what modifications in the indicated procedures are required.

In taking up this problem it was decided to use a charge which consisted of, approximately 70 per cent of copper, 25 per cent of lead, and 5 per cent of tin. Furthermore it was thought advisable to use virgin metals in preparing the charge as there would be less chance of introducing impurities. However, in the later experiments described in this series scrap metal was used in conjunction with small quantities of the virgin metals. The record of these experiments follows:

Summary and Conclusions of Series 5

Div. 1.—Castings Nos. 38 to 42 were made from a charge consisting entirely of virgin metal.

The charge from which castings Nos. 38 and 39 were made was heated to and poured at 1900 degrees Fahr. The molten metal was allowed to cool naturally. All of the castings were segregated. The average modulus of rupture was approximately 33,000 pounds.

The charge from which castings Nos. 40, 41, and 42 was made was heated to 2200 degrees Fahr. In the case of casting No. 40, the metal was poured at 2200 degrees Fahr.; but in the case of castings Nos. 41 and 42, the metal was chilled

to 1860 degrees and then poured into the molds and allowed to cool naturally. All of the castings were free from segregations. The average modulus of rupture for the three castings was 39,000 pounds.

It should be noted here that the loss of tin due to oxidation and volatilization was relatively small.

Div. 2. Castings Nos. 43 to 48 were made from a charge consisting of scrap metal, and relatively small quantities of tin and lead.

The charge from which castings Nos. 43 and 44 were made was heated to and poured at 1660 degrees Fahr. The molten metal was allowed to cool naturally in the mold. Both castings showed segregations. The average modulus was 33,550 pounds.

The charge from which castings Nos. 45, 46, 47 and 48 was made was heated to 2100 degrees Fahr. In the case of castings Nos. 45 and 46, the metal was poured at 2100 degrees; but in the case of castings Nos. 47 and 48, the metal was chilled to 1760 degrees Fahr. and then poured into the molds. All of the castings were free from segregations. The average modulus for these four castings was 38,000 pounds.

It should be noted in this case, however, that the loss of tin due to oxidation and volatilization amounted to 1.0 per cent.

Conclusions. The results obtained by conducting this series of experiments indicate:

(1) That it is possible to produce high-lead castings free from segregations if the processes are controlled within the limits indicated in previous sections of this paper.

(2) That the charge prepared from virgin metals must be heated to a higher temperature than a corresponding charge made largely of scrap metal if castings to be made from it are to be free from the defects known as segregations.

This may be accounted for in part, at least, in terms of the well-known law in regard to a pure solvent having a higher freezing-point than when a non-volatile substance is dissolved in it. In other words, solid solutions like fusible alloys have

a lower melting-point (or freezing point) than either of its components. This principle has received frequent and various applications in foundry practice.

(3) That castings made from a melt containing 26 per cent of lead, heated to a temperature as high as 2200 degrees Fahr., and poured into the molds at that temperature, or chilled to 1760 degrees Fahr., and then poured, will be free from segregations.

(4) That the modulus of rupture is not decreased by heating charge to the highest temperature indicated, but that there is considerable loss of the more volatile components, due to oxidation and volatilization.

VI *General Summary*

By these series of tests it has been shown:

(1). That the elimination of impurities from the melt and thorough mechanical mixing of the components of the molten metal are not sufficient to insure the production of castings free from segregations. The control of these two factors, however, is essential as differences of composition from one portion of the melt to another, particularly at the time of pouring are very frequently the cause of segregation.

(2) That the segregated portions of a casting always contain a smaller percentage of tin than the good portions. If these variations be expressed in terms of percentages of the elements it was found that the average variation for tin was 25.58 per cent and less than 2 per cent for either lead or copper.

(3). That the loss due to oxidation and volatilization was greatest in the case of tin, but in no case was it as large as was anticipated,—seldom amounting to more than one per cent in melts which had been heated to the highest temperatures used.

(4). That all castings made from a charge which had not been heated to a temperature above 1800 degrees Fahr., or having been heated to a higher temperature were cooled to a temperature much below this, contained segregations.

The structure of the segregations occurring in castings made from charges which had not been heated to a higher

General Summary of Moduli

Non-segregated castings

Temp. at which melt was poured Dgrs. Fahr.	Area of Cross Section square inch	Breaking Load Total in pounds	Breaking Load per sq. inch Cr. Sec. in pounds	Modulus of Rupture in pounds
2050	8.270	32,800	3,961	35,640
2000	8.347	36,558	4,381	38,723
1800*	8.357	38,135	4,580	40,679
1600*	8.371	34,125	4,077	36,195
2200	8.106	36,220	4,460	40,930
1860**	8.635	38,710	4,485	38,560
2100	8.395	37,070	4,410	39,010
1760**	8.443	36,310	4,300	38,770
Average	8.366	36,241	4,332	38,563

Average "modulus of rupture":

Of "non-segregated" castings..... 38,563 lbs.
Of "segregated" castings (next page)..... 33,037 lbs.
Difference ..... 5,526 lbs.
Percentage variation ..... 14 per cent

*This melt was heated to a temperature 200 degrees higher and cooled to this temperature before pouring.

**This melt was heated to a temperature 400 degrees higher and cooled to this temperature before pouring.

"Segregated" castings

Temp. at which melt was poured Dgrs. Fahr.	Area of of Cros. Sec. square inch	Breaking Load Total in pounds	Breaking Load per sq. in. Cross-Sec. in pounds	Modulus of Rupture in pounds	% Variation in Tin between segregated and good sections
1800	8.229	30,960	3,760	33,960	18.50
1600	8.438	32,963	3,905	34,353	26.90
1400	8.212	30,983	3.772	34,164	31.20
1800	8.443	33,660	3,986	35,100	28.99
1600	8.323	25,950	3,120	27,890	25.27
1600*	8.491	31,520	3.720	32,275	15.16
1900	8.347	31,860	3.818	32,985	35.10
1660	8.539	32,995	3,865	33,565	25.45
Average	8.377	30,111	3,743	33,037	25.58

*This melt was heated to a temperature 200 degrees higher and cooled to this temperature before pouring.

temperature than this, or having been heated to a higher temperature and were chilled to a temperature much below 1700 degrees Fahr., indicated that the filling-up process had been greatly hindered by the higher viscosity of the alloy at the lower temperatures.

(5). That castings made from charges heated to 2000 and 2200 degrees Fahr., and then cooled rapidly by a chilling process to approximately 1800 degrees Fahr. before pouring

the metal into the molds exhibited a structure that was not quite so coarse and loose as those poured at the temperature to which the charge was heated.

(6). That charges consisting entirely of virgin metals require a higher melting temperature than those made largely of scrap metal if the castings are to be free from segregations.

(7). That castings made from a melt containing as much as 26 per cent of lead, heated to a temperature as high as 2200 degrees Fahr., and poured into the molds at that temperature, or chilled to 1700 degrees Fahr., and then poured, will be free from segregations.

(8). That the average modulus of rupture for castings free from segregations is 14 per cent greater than for castings containing these defects. Furthermore, that the modulus is not decreased by heating the melt to the highest temperature indicated, namely 2200 degrees Fahr. For example, castings made from a melt heated to 2000 degrees Fahr. and chilled to 1800 degrees Fahr. before pouring showed a modulus of 40,000 pounds, the highest noted in all the series. The tables showing the moduli for all castings appear on page 529.

VII *General Conclusions*

1. The physical properties of an alloy depend on both its chemical composition and its physical structure.

2. For a given material, the components of which have been thoroughly mixed, the constitution and structure of a casting will depend largely on the thermal conditions to which it has been subjected.

3. The prevention of segregation in alloys where it occurs to a serious extent is a difficult matter and can be accomplished only by the careful control within certain limits of the factors indicated in the foregoing pages.

4. The data obtained during the progress of the investigation and presented in this paper with reference to the limits within which the factors, upon which the solution of the problem depends, must be controlled has made it possible to formulate a series of procedures by which castings (journal bearings) made from a high-lead bronze (Cu., 70 to 75 per

cent, Sn., 5 to 6 per cent, Pb., 20 to 26 per cent) may be produced so as to be free from the defect known as segregation.

The proposed method is as follows: The charge may be made from either scrap or virgin metal. Care should be exercised throughout the entire procedure to prevent the introduction of impurities. The charge should be heated to approximately 2000 degrees Fahr., chilled to 1800 degrees Fahr., and then poured into the molds.

The molten metal should be thoroughly mixed by puddling. On removing the metal from the furnace, a small percentage of phosphor-copper should be added to reduce the oxides, the dross removed by skimming and the metal stirred vigorously.

In this connection it should be noted that unless the sand is comparatively dry and is rammed firmly into the mold the surface of the casting will exhibit the so-called sand-burns.

The practicability of the method is indicated by the fact that the procedures as formulated now constitute the foundry practices in the plant of the company manufacturing castings of the type known as high-lead bronze bearings.

It is a matter of record that castings made according to these procedures rarely contain segregations and exhibit a modulus of rupture which is much higher than that shown by castings produced by the usual procedures.

The slight increase in loss of tin and lead through volatilization and oxidation as the result of heating to the temperature recommended is more than counter-balanced by the elimination of former losses by rejections due to the presence of segregations in the castings.

Discussion—Segregation in Castings Made of High Lead Bronze

E. J. DECKER.—I would like to ask a question. Did you find it necessary to superheat the metal in all cases and then chill it by adding material of the same grade before pouring?

R. E. LEE.—No, we did not, sir.

E. J. DECKER.—In other words, if it was just heated to 1800 degrees and poured at that temperature the result would be the same as heating to 2000 degrees and then chilling it?

R. E. LEE.—No. I think perhaps the difference in my statement there is due to the sense in which you use "superheat." Of course, we are compelled to simply reach our conclusions as a result of the work we did, but we did not find that by first heating to 1800 degrees and then pouring at that temperature we got as good results as when we heated to the higher temperature of approximately 2000 and then let it cool. We found that the crystals formed were better. You see, there was the whole theoretical field that was treated in presenting the paper. It leaves the metal in such a high condition of temperature relatively to what they started from that they do not have what they call "diffusion", because the whole process is a process of diffusion. Now, those crystals in that case have a tendency to form in pockets and large crystal formations, one on one end and another on another end, and it has a tendency to what we call "wall out" other crystals in relation to them. Now, if you raise your temperature then to approximately 2000 degrees, as indicated by our survey; that is, I say it in that rather restricted sense because this is a very wide field that we have open before us, we found that the crystal formation was better, and it was probably my own fault that I did not emphasize that part of the paper more. I wonder if that answers it.

E. J. DECKER.—Yes. I also wanted to ask: Does the same temperature apply to anything between 20 to 30 per cent of lead?

R. E. LEE.—Yes, about the same. That is, in formulating the procedure of the plant we make no distinction.

E. J. DECKER.—Again, you said in pouring new metal alloys it was necessary to pour at higher temperatures than old metals. Were your experiments all with new metals?

R. E. LEE.—Well, I didn't separate my experiments, although I have a complete record on file of the different data, but we did have to heat the virgin metals to a higher temperature.

E. J. DECKER.—You pour out of that at the same temperature?

R. E. LEE.—Oh, yes; we have the series of data for all of that. We attempted to pour at all of them down as low as 1400 degrees. We didn't attempt any below 1400. We poured at all the way from 1400 up to about 2000 or 2400 degrees. Of course, I didn't report that this afternoon.

E. J. DECKER.—But the best temperature is 2000 reduced to 1800?

R. E. LEE.—That, I say, makes good foundry practice.

E. B. PERRY.—I would like to ask Mr. Trace if he would still have the same temperature with the lower lead content, say from 10 to 20, as when you have the high average.

F. B. TRACE.—Mr. Chairman, that was one of the conditions under which we worked. In the beginning our purpose was to ascertain the result, not in lead down as low as 10 per cent, but our lead was restricted to between 20 and 30 per cent. So we did no research work on any castings that contained less than 20 per cent of lead, so I could not tell you exactly whether it would hold out in the casting below 20 per cent of lead or not. However, I imagine it would.

E. J. DECKER.—I would like to ask another question: Did you experiment with the percentage of tin?

R. E. LEE.—Not within any great limits. No, we hold that that would apply to the content of 20 to 30 per cent of lead. You see, the field was so limited. Our problem was a matter of high lead bronze at the different temperatures, and we hadn't turned our attention to any variations from that

so that we can only speak this afternoon to a very limited field.

R. J. ANDERSON.—It is not altogether clear to me what he means by segregation and what the mechanism of preventing is. I think he ought to tell us about that.

R. E. LEE.—Mr. Chairman, that was the particular phase of the subject that from my standpoint as a physical chemist was interesting, but I felt this crowd this afternoon would not be interested—that is in the mechanism of segregation. I just touched on that when I attempted a very superficial survey of the application of the phase rule and the eutectic mixture. Now, if the man who put the question will ask me just a more pointed question, as to whether he wants me to go into the application of the phase rule, I would be very glad to do it.

R. J. ANDERSON.—Would you tell me the mechanism of segregation by heating to 2000 degrees and then cooling down to 1800 degrees and then pouring at that? I don't see what goes on there.

R. E. LEE.—We care less about the 1800, only that we don't want it to go too low. But according to our paper and the findings, we intend that the metal should be heated to that temperature to secure the viscosity which is necessary to the proper crystal formation and for the proper separation out of the excess of the ingredients of the eutectic mixture.

CHAIRMAN J. L. JONES.—I think this paper will be available and that Mr. Anderson can probably ascertain these points that are in doubt at the present time. I suppose that the meeting hardly cares to have a lengthy discussion of the phase rule.

R. E. LEE.—Mr. Chairman, this man has placed his finger on a very important point of the paper, as to how the raising of the temperature to 2000 degrees or 2200 degrees prevents the segregation. That is the very vital point of the paper, as to how the crystals do not "wall off" and do not form the loose, spongy structure and do not produce segregation. Of course, it takes some time to discuss that, but that is the point.

W. L. JACKSON.—Mr. Lee, I would like to ask you what percentage of virgin metal and what percentage of scrap you use.

R. E. LEE.—We used a lot of different combinations.

W. L. JACKSON.—What do you find as most applicable there?

R. E. LEE.—I should say from the general finding of the paper that the using of scrap metal with just about sufficient metal, possibly lead or tin, to build it up to the specifications, makes one of the most satisfactory combinations that we experimented with.

W. L. JACKSON.—In the paper under discussion you stated that when you use virgin metal you must run your temperature higher, say to 2200 degrees. If you use, say, 50 per cent virgin metal and 50 per cent scrap that would be a ratio there that you would have to run your temperature before you chilled, would it not?

R. E. LEE.—No. You might expect that; that is true enough. You might expect there would be a ratio there. We don't find that when we use we will say, 75 to a 100 per cent virgin metal, the temperature made any difference. You might if you used the scrap material in abundance, that is, a larger percentage, and then put in the virgin metal to build up, but that would not alter the temperature.

W. L. JACKSON.—You speak of chilling: You mean that you allow the metal to cool down?

R. E. LEE.—No. In some of our chills here—these were chilled differently. Some were chilled one way and some others. In some of these we actually chilled by putting into the pot borings of the same metal. Then, of course, we used other metals.

W. L. JACKSON.—Mr. Gill, how long does it take you to cool your metal down?

J. R. GILL.—We don't know. That was not our experiment. We poured the metal at about 1900 degrees or so.

W. L. JACKSON.—In the high lead alloy there is a certain amount of separation. I would expect it to be explained

on scientific principles. Do you find then, that there is a separation of it before you let it stand at all?

R. E. LEE.—Well, of course, we would only allow it to stand just while we are pouring, and we found that the last metal poured from the pot gave us a casting without segregation.

W. L. JACKSON.—Without a higher percentage of lead than the first?

R. E. LEE.—Yes.

J. R. GILL.—I think I know what you have in mind, that the casting begins to sweat beads of lead.

W. L. JACKSON.—No. Wouldn't you expect that there would be perhaps a higher percentage at the bottom than at the top?

J. R. GILL.—Our theory on that is that if you don't have the metal heated quite hot it forms a very thin film and that film doesn't mix very well.

DR. BRUNO WOYSKI.—I would like to ask a few questions of Mr. Lee to correct my understanding of the copper-lead mixture. You are speaking of the eutectic mixture, and the general understanding is that the copper-lead is not eutectic there, and that when you go higher in copper the liquid goes into permanent solution up to 30 per cent, where the second liquid solution begins to form. This eutectic mixture in this series is not quite clear to me. The lower pouring temperatures probably prevent the segregation because you have a permanent liquid solution for copper and lead, but that is not above 30 per cent. Now, tell us more about that. The more it has to be cooled the less segregation there is of it.

CHAIRMAN J. L. JONES.—You still think there would be some segregation notwithstanding the rapid cooling?

DR. WOYSKI: Well, the cooling is rapid enough.

R. E. LEE.—Mr. Chairman, is that a question for me to answer?

DR. WOYSKI.—Yes, I do put that as a question, because you say that the phase rule doesn't explain your results there.

R. E. LEE.—Yes, I said that that was the point, that in making up the specifications different industrial corporations paid no attention to prescribing a mixture of elements that would make a eutectic mixture. A eutectic mixture, as you gentlemen know, is an approximation to causi-crystallization; that is to say, it is not a causi-crystallization but is just a close crystallization of the crystals together. Now, I have made my statement that there would be no difference, but because we have an excess of other elements there we must provide for prevention of segregation in some other way than relying upon a eutectic mixture. I thought I made that clear.

DR. WOYSKI.—Is it possible to have the eutectic mixture in copper-lead?

R. E. LEE.—No.

DR. WOYSKI.—Your eutectic mixture remains a chemical compound. Is there such a thing in copper-lead series?

R. E. LEE.—No. We don't regard them as even having a different chemical composition. The only characteristic thing about them is their freezing point. That is the only thing about a eutectic mixture, is its freezing point.

DR. WOYSKI.—If it is high it will freeze out and separate crystals from it?

R. E. LEE.—Yes. That point that you just referred to is definitely settled by a French metallurgist. I have several paragraphs here devoted to his work. For instance when they took water and salt and got down to what is known as the "eutectic mixture" they crystallize out together in the form of ice; that is not a chemical union. That is the eutectic mixture of salt and ice and that is the low melting point, and it is the same way in the making of a bronze bearing. We can not have eutectic mixtures. Therefore, instead of getting the desirable thing that we have in the case of water and salt crystallizing out, where they scatter uniformly through one another, we have picked some other method for the placing of the crystals closer, and you can only do that by getting it to a sufficiently high temperature where there will be sufficient viscosity for the crystals to grow naturally without walling off.

DR. WOYSKI.—It still doesn't make it clear. Why do you use this eutectic mixture to avoid segregation?

R. E. LEE.—Because, for example, your zinc and lead; you take your zinc and lead and you have a eutectic mixture?

DR. WOYSKI.—Yes.

R. E. LEE.—When you have a eutectic mixture can there be such a thing as segregation?

DR. WOYSKI.—No.

R. E. LEE.—All right; then naturally we were searching for a solution of the problem and in doing that you are going to study the conditions that prevail in a eutectic mixture. The conditions that we find in a eutectic mixture are for the easy growth of interlacing crystals. Therefore, naturally we would be seeking for some segregation which would enable the crystals to grow when it is not a eutectic mixture.

DR. WOYSKI.—Is it possible to form a compound like that?

MR. LEE.—That would be a difficult thing according to all the findings in the paper. We found that it was impossible to do that.

E. G. FAHLMAN.—We have been doing some work recently, and your report makes some things look rather interesting to me, as compared with the results that we found. We had alloys of various kinds and we had three pots. It happens that we have been getting a pot in three different foundries. The result was that the foundry in one experiment puddled a very high tensile strength up to 37,000 pounds. In test bars in another one there is segregation. In one case we find segregation and in the other case we do not. In one case the tensile strength was lower than the elongation. Now, according to that, it almost looks to me as though the foundry that got the high tensile strength got it as a result of getting segregation. I was wondering if it would be entirely possible. You people probably ran these tests over a long time, did you not?

R. E. LEE.—Over a period of one year. Well, I have not been at foundry work very long, about four or five years, and I happened to be in two or three foundries where they never had that thing. I found that where they could get a good

superintendent and good men to work, the segregation was less. Why wouldn't it be entirely possible that it was a more or less psychological influence on the men in the foundry, because the way I understand the phase rule it doesn't account for that.

W. L. JACKSON.—I would like to ask one more question. Mr. Lee, do you find that in the places where they have used various furnaces it was entirely brains that helped it, or did the furnace help it? This gentleman thought that perhaps we could use any furnace if we had brains.

J. R. GILL.—We got the same results whether we used brains or no brains; we found that we could make rotten castings from virgin metal or secondary metal, it just depends upon how you treat it.

C. UPTHEGROVE.—I would like to ask Professor Lee one question along the same line of Mr. Anderson's, and that is, in getting this preliminary heating and then dropping it down, will you explain the idea? Do we not understand that the control of the crystallization may be largely influenced by the temperature being dropped down to the point of solidification?

R. E. LEE.—It naturally would be controlled some, but I think it would play an exceedingly minor part. Did I understand you to say the temperature below the crystallization point?

C. UPTHEGROVE.—Just at crystallization and immediately below.

R. E. LEE.—Well, certainly, it will affect the crystallization, but the point is that the opportunity for these crystals to place themselves is of more importance than the direct effect on the crystal by the temperature at which it is passing into the crystal form, because these crystals just do not form and remain in that size, but they grow and diffuse. Therefore, if the liquid is not volatile or sufficiently molten, there is no opportunity for the crystal to grow.

C. UPTHEGROVE.—I don't desire to prolong this indefinitely, but I thought it had been clearly shown by someone back in

1908 and previous to that, and clearly demonstrated, that the crystal growth depends very largely upon two things, the temperature, and that at a certain temperature you have a linear function and the viscosity becomes a linear function. That would have a great deal to do with it in determining what your relation to the crystals would be. And also, as Mr. Anderson says, I do not hardly see the explanation of the mechanism or how you manage to control the segregation.

R. E. LEE.—The drop to 2000 degrees is of minor importance. We have to get it to 2000 degrees to get sufficient volatility of the mixture, that is, a point where there is sufficient room in which the crystals can grow, but that it must not cool to below 1800 degrees. It must not drop below that. We got practically nothing out of the experiments on the chilling methods, but you have to have the temperature to 2000 degrees.

CHAIRMAN J. L. JONES.—I think Professor Lee's practice can be summed up in the ordinary foundry practice of melting hot and pouring at certain temperatures, and he has obtained certain results which are presented in rather a striking way.

Brass Forgings

By C. G. Heiby, Port Huron, Mich.

To some persons the production of brass forgings may seem like a subject out of place for discussion by foundrymen, as it is not altogether a foundry proposition. It has been proved by experience that the manipulation of the metal by mechanical means outside the foundry adds greatly to its physical qualities. However, it is recognized that the brass foundry has a joint interest in the subject; it is responsible for the alloy used, which is important. The reason for presenting this subject is that foundrymen will be interested in a comparison in the quality of castings and forgings.

As far as is known by the writer, no record is available to show when brass forgings were first produced. Older text books on engineering materials generally state that brass can be cast and rolled, but can be forged only with difficulty or not at all. It is generally known, however, that the process was greatly developed on this continent during the late war, and was a reliable means of meeting the rigid specifications covering small brass parts for munitions. Since the close of the war much progress has been made in the application of this process in the production of standard commercial parts.

How Forgings Are Produced

Brass forgings are produced by squeezing or extruding a heated billet between closed or partly closed dies operated by presses of varying construction, according to the design of the piece being produced. It is possible to forge some simple parts in ordinary single acting crank presses, while other parts require double-acting presses with closed dies. In some designs hydraulic presses are advisable.

As the gating and pouring of each new casting is a problem in itself to the foundryman, so the production of each brass forging must be considered separately. After considerable experience it is found that they can be classified and the

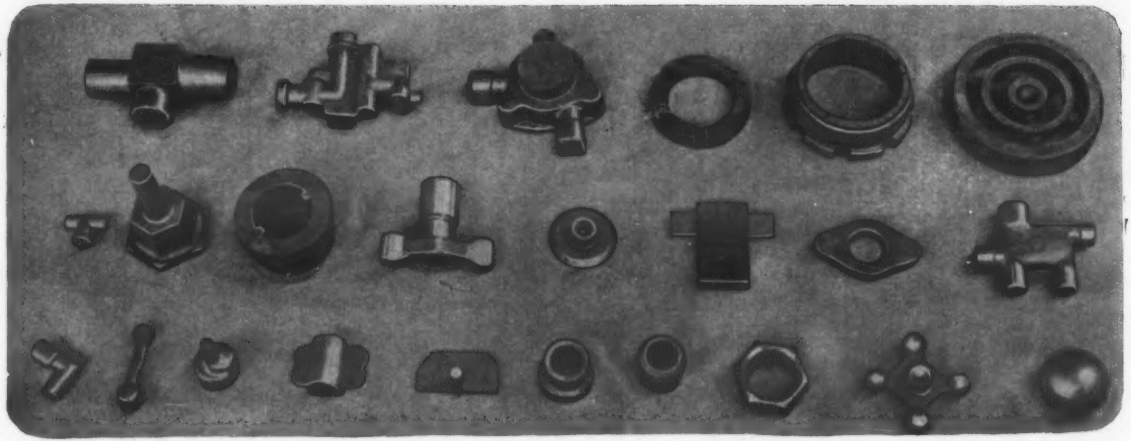


FIG. 1—A NUMBER OF TYPICAL EXAMPLES OF BRASS FORGING, SHOWING THE RANGE OF WORK TO WHICH THE PROCESS IS ADAPTED. THE STEPS BY WHICH FORGINGS OF THIS KIND ARE SHAPED BY MEANS OF SQUEEZING OR EXTRUDING IN DIES ON POWER PRESSES ARE INDICATED IN FIG. 2.

rules applying to the class to which the forging belongs can be applied.

The best way to secure blanks or billets for brass forgings is to cut them from extruded rods. Except for the fact that brass forgings are in many instances taking the place of sand castings, the foundryman is not interested beyond the production of the billet for the ordinary brass rod extrusion press.

In the early stages of development in the brass forging industry, it was thought that ordinary sand castings could be successfully squeezed in closed dies and made to meet the same physical requirements as truly forged brass.

In every case this experiment proved a failure, as did also the attempt to use sand cast blanks of the same form as extruded blanks, and the failure was principally due to oxides forming between the crystals in the casting. No amount of squeezing under pressure would cause the oxidized crystals to weld together. Since test bars taken from squeezed sand castings did not meet requirements, this method was abandoned.

It was also found impractical to partially forge a piece in the finished forging die, with the intention of reheating the blank and striking a second time to complete the forging. Partial forging in the finish die reveals the fact that brass when flowing in the die, opens up like a sponge, and if the partially forged piece in that condition is exposed to the air, or reheated, an oxide forms which prevents re-uniting the crystals by further manipulation.

On this account it has been found most practicable and economical on some shapes to extrude a bar of proper cross section from which the forging blank is cut.

Good brass forgings have been made in two forging operations by using two sets of dies. That is a breaking down die and a finishing die, but in every case it is necessary to entirely fill the die, and squeeze the metal sufficiently to eliminate porosity and thus prevent the forming of oxides. It is, of course, necessary to trim the flash and all surplus metal from the partially forged piece before heating for the second operation. It is advisable wherever possible to forge brass in one

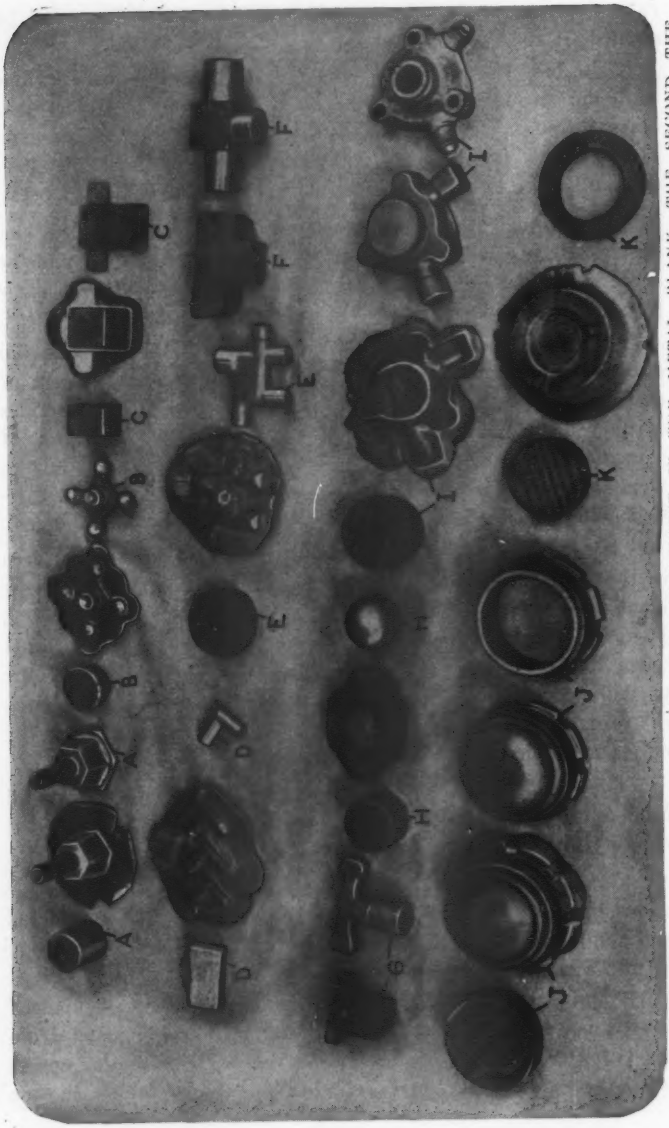


FIG. 2—IN EACH SERIES OF THREE FIGURES, THE FIRST IS THE METAL BLANK, THE SECOND THE FORGING AS IT LEAVES THE DIE, AND THE THIRD THE FINISHED FORGING

operation as this practice not only reduces the salvage metal to the minimum, but also insures a more uniformly reliable structure.

Used Chill Cast Blanks in War

A great many good brass forgings were made during the war from chill cast blanks. These blanks, usually in the form of round flat disks, are poured in open cast iron chills, pouring each cavity in the chill separately. The top and bottom sides of the blank are then machined to remove scale and oxides. The scale from the periphery of these blanks was not removed.

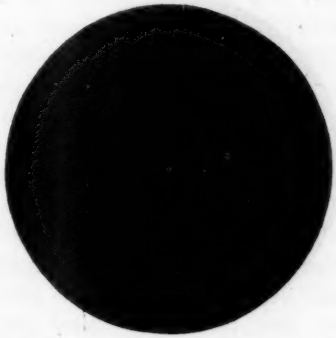


FIG. 3—SAND CASTING, SHOWING OPEN-GRAINED STRUCTURE. TENSILE STRENGTH 30,000 POUNDS PER SQUARE INCH

and this frequently resulted in flaws in the forgings. If the test bar was taken from one of these forgings, its failure was almost a certainty, with the resultant rejection of the whole series covering a large quantity of perfectly good forgings, together with some questionable ones. This experience proves without question the desirability of the extruded blank.

Numerous experiments and actual practice prove that standard brass forgings properly made of inexpensive alloy, are 80 per cent stronger than sand castings of a more expensive alloy.

The use of brass forgings is limited, but not to such an extent as upon slight consideration might be supposed. Their use

is most desirable when a nonferrous part is wanted and when greater strength and greater uniformity in strength and form is needed than can be secured in the ordinary run of brass sand castings.

There is also a large and important field for their use wherever great density of structure is desired, or where the possibility of porosity is present, such as is the case with sand castings. Practical examples in this field are high pressure gas valves for use on steel bottles containing oxygen, carbonic acid gas, and other gases which are stored under high pressure. No one has been able to make sand castings sufficiently dense

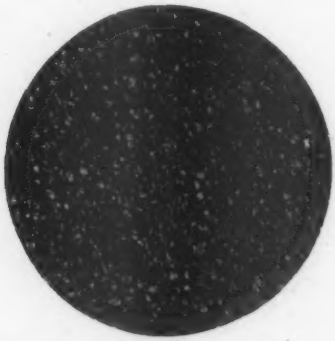


FIG. 4—BRASS FORGING, SHOWING FINE-GRAINED STRUCTURE. TENSILE STRENGTH 60,000 POUNDS PER SQUARE INCH

to hold these gases and it has become standard practice to make them of brass forgings.

Forged brass gasoline pipe connections for automobiles such as elbows, tees, and oil pump bodies are also examples in this line. Their great density and uniformity eliminate the piece by piece inspection and pressure test which is necessary with sand castings, also the possibility of gasoline or oil seepage and the greasy surface which gathers dust and dirt and is altogether objectionable.

Forged brass pump valve seats are meeting with great favor because of their density and consequently longer life.

They can be made lighter and stronger and have a larger waterway, eliminating friction, thereby making a pump using forged brass valve seats more efficient.

Due to the greatly improved physical qualities and uniformity of form of brass forgings it is often possible to lighten parts appreciably and still retain a higher factor of safety. This feature alone is of great importance in the construction of all apparatus where it is desired to have great uniform strength with minimum weight, such as automotive vehicles, aircraft, etc. and can be compared with the use of special alloy steels for the same reason.

During the war millions of time fuse parts were made by this process and thousands of test bars pulled, prove without question, the uniformity of strength and structure.

Brass forgings come from the dies uniform in dimensions and they are clean and free from sand. On this account, they are preferred because they can be chucked true for machining, and because they are, in spite of their great density, easy on the cutting tools. Thus they can be machined uniformly accurate, each piece being of exactly the same structure.

Brass forgings made in properly designed dies, in presses of proper capacity and of uniform alloy, can be held to dimensions varying only .005 of an inch on diameters and .010 on lengths. This feature is considered of great importance by production engineers from the standpoint of efficiency in machining.

Due to the finished quality of the surface as they come from the die it is often possible to eliminate machine finishing operations entirely, and on polished parts a buffing operation is often all that is required.

For illustration, finished forged brass hexagon nuts do not require milling on the flats. The hole is forged the right size for tapping and is exactly in the center, making it unnecessary to use a drill before tapping. This reduces the chip salvage to the minimum.

An idea of the range of commercial work which has been successfully handled by one brass forging company is given in

Figs. 1 and 2, which show respectively, a collection of finished parts made from forgings, and a group of finished parts together with the untrimmed forgings, and the blanks from which these pieces are produced.

Composition of Metal

Unlike sand castings, which allow the use of an unlimited number of mixtures of brass and bronze, the process of hot forging allows the use of a comparatively small number of mixtures. This is due to the fact that there are comparatively few brass and bronze mixtures which can be worked hot under pressure in a confined area, without splitting due to a cause known as "hot short."

In all forging mixtures, copper appears to be the governing element. The forging mixtures may be divided into two main classes—mixtures low in copper and those high in copper.

The mixtures low in copper comprise the largest percentage of forging mixtures used on a commercial basis. The composition of this mixture is as follows: Copper, 56 to 63; lead, 0 to 3; tin, 0 to 3; iron, 0 to 3 per cent; and balance, zinc.

Mixtures containing less than 56 per cent copper are brittle, and hence are not used. Mixtures containing above 63 per cent copper are hard on the dies, causing them to crack. A mixture of this copper content also shows cracks in the forging, due to its "hot shortness" which seems to develop at about this point.

Mixtures containing from 63 to 86 per cent copper, do not appear to lend themselves to the hot forging process in an enclosed area, such as a forging die.

To the mixture of the second class belong compositions containing from 87 per cent to 100 per cent copper. To this class belong the compositions known as the aluminum bronzes and pure copper.

Physical Properties

The physical properties of a forging depend principally on the composition and the "amount of work" performed on the metal during the forging operation. It is natural to expect

higher physical properties from mixtures containing small amounts of hardeners such as tin, iron, manganese, etc. than from mixtures that are entirely free from these elements.

By the term "amount of work performed" is meant, the amount of flow or movement, that has taken place in the metal during the forging operation. Forgings in which the amount of metal movement that has taken place is great show better physical qualities than do those in which the metal movement is small, because of the finer crystal structure produced during the operation.

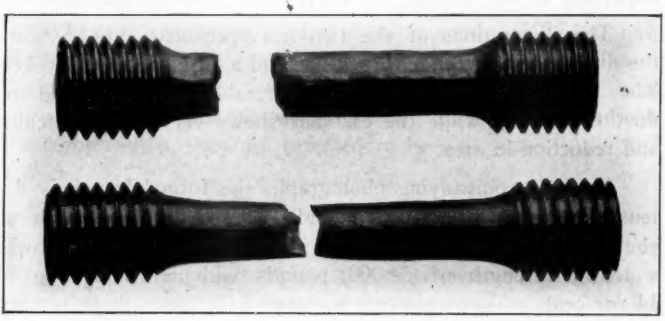


FIG. 5—(TOP) SAND CAST TEST BAR. (LOWER) FORGED TEST BAR

The physical properties of a free cutting mixture containing 58 to 60 per cent copper, 1.5 to 2.5 per cent lead, and 37.5 to 40.5 per cent zinc are as follows: Yield point, 28,000 to 35,000; tensile strength, 55,000 to 65,000; elongation, 25 to 40 per cent; and Brinell hardness (10 millimeter ball),—80. The physical properties of forged aluminum bronze containing from 86 to 90 per cent copper, 1 to 2 per cent iron, and balance aluminum are as follows: Yield point, 75,000; tensile strength, 104,000; elongation, 15 per cent; and Brinell, (10 mm. ball), 190.

Microstructure of Forgings

The reason for the remarkable physical qualities of a forging can readily be understood of a study of its microstructure.

For purposes of comparison, the microstructures of a forging and a sand casting are shown in Figs 3 and 4.

In examining the microstructure of a sand casting, it is seen that the structure is coarse and open grained in character, and that the lines of division of the crystals are pronounced. In examining the microstructure of the forging, it is seen that the structure is fine grained, compact and uniform, and that the lines of division of crystals are absent. It is the working of the metal under a pressure of 200 tons per square inch, which produces this close grained, homogeneous crystal structure, imparting to the forging its exceptional physical qualities.

The illustrations of the two test specimens, Fig. 5, show the difference between a forged bar and a cast bar when broken. The forged bar breaks after considerable stretching and reduction in area, while the cast bar shows very little stretching and reduction in area.

In the accompanying photographs the forged bar showed a tensile strength of 60,000 pounds per square inch with an elongation of 40 per cent in two inches. The cast bar, showed a tensile strength of 34,000 pounds with an elongation of 14 per cent.

In the preparation of this paper the writer is indebted to F. M. Levy, metallurgist of the Mueller Metals Co. for the laboratory information given.

Melting Aluminum for Rolling into Sheet

By JOHN A. LANGE, Western Springs, Ill.

Melting aluminum for rolling into sheet is an important detail of aluminum rolling mill practice, and unless great care is exercised in the melting operations, perpetual troubles, with attendant heavy losses either to the mill or to the ultimate user, will be encountered.

When the writer completed, in about September, 1917, the new aluminum rolling mills for the Bremer-Waltz Corp. at St. Louis, it was decided to experiment with different types of furnaces and slab molds. Four types of melting furnaces were tested. For identification, they are referred to here as types "A," "B," "C," and "D."

Melting Pots—Type "A" Furnace

Six cast iron pots were used, each having a capacity of 300 pounds of aluminum when the metal was 3 inches below the top of the pot. This type of furnace requires considerable hand stirring, ladling, etc. This is most exhausting during hot weather and makes it difficult to retain the men, although the poundage rates were 20 per cent higher than for the combination revolving and tilting type of furnace.

The objections to this furnace are:

1 A large gas consumption per pound of aluminum recovered.

2 The cast iron pots only lasted about 60 to 80 heats and then either had to be removed or the risk of an early break with attending hazards was imminent.

3 Considerable loss and injury to the metal was certain in case any aluminum was spilled into the furnace chamber. The brick lining had to be repaired about every 1000 heats, and replaced about every 3000 heats.

Although every precaution was used to charge dry metal into the bath in the pots, there were several explosions, perhaps due to moisture condensing on the cold metal. It was found

dangerous to melt scrap that was coated with enamel, or utensils which had been used to hold sodium silicate (for sealing of corrugated paper cartons).

However, the iron pot method had some advantages. Slabs could be made continuously and rolled directly from the molds. The melting loss was low and a small absorption of iron occurred. Nevertheless, the hardships of this method on the men, the high labor cost, and high gas cost were not sufficiently offset by the saving in metal loss, and the type eventually was discarded.

Tilting Reverberatory Melting Furnaces—Type "B".

Experiments were conducted on two tilting reverberatory fur-

MELTING FURNACE REPORT Date.....

Shift ..... Furnace No. ..... No. .....

Charge No.	METAL CHARGED							METAL RECOVERED						
	No.	Ingot	Scrap	Spills	Skims	Dross		No.	Slabs	Ingot	Spills	Skims	Dross	
1														
2														
11														
12														
Total														
Per Cent														

RATE SUMMARY

	NAME	Pounds Melted	Rate Per Ton	Amount Earned
Head Melter				
Asst. Melter				
Helper				
Helper				
Helper				

Fuel Stop ..... Time Stop .....

Fuel Start ..... Time Start .....

Fuel Used ..... Time Total .....

Labor Per Ton Aluminum Recovered .....

Fuel Per Ton Aluminum Recovered .....

REMARKS .....

Foreman .....

FORM OF MELTING REPORT USED IN MAKING TESTS OF FOUR TYPES OF FURNACES

naces, each having a capacity of 400 pounds of aluminum. These furnaces were heated by open gas flames. The gas and air were supplied by two separate lines, and mixed by hand-controlled valves. Since the flame was enclosed in the furnace, it was difficult to watch and control the mixture. The furnace was charged through the top, skimmed, and poured through the front opening. It had a cast iron pouring spout and required hand ladling. The ladle had to be preheated, and 110 feet of gas for ladle heating per heat were consumed in addition to the gas consumption listed in Table II.

The objections to this type of furnace were a large gas consumption and a heavy melting loss. Also, the linings had to be repaired every 500 heats, and entirely rebuilt about every 1500 heats. The metal seeped into the brick lining to the extent that when the furnace was rebuilt about 30 pounds of burnt metal were recovered.

One uniform lot of ingot was divided between types "A," "B," and "C" furnaces and the slabs were subsequently rolled under exactly the same conditions. When the sheet was used for an exceptionally deep and difficult draw, the metal produced from the type "B" furnace was slightly granular after drawing, though not enough to cause rejection.

Combination Revolving and Tilting Reverberatory Furnaces—Type "C"

Two furnaces of this type were used, having a melting chamber 33 inches in diameter and 72 inches long, with a 5½-inch low silica content, special refractory brick lining set in a cast iron shell. The pouring end had a 9-inch diameter pouring opening, while the charging and firing end of the cylinder had an 18-inch opening which was reduced to 9 inches by a swinging door. The furnace was fired through this 9-inch opening. The furnace was skimmed through the 18-inch charging opening. A pit about 2 feet deep was built below the furnace to store dross after it had cooled.

The gas and air were brought to the furnace in separate pipes and separate hand control sliding valves were used to control the mixture. The nozzle fired across an 8-inch gap; this

Table I

MELTING LOSSES*

Furnace	100 per cent virgin	70 virgin 30 mill scrap	100 per cent mill scrap	100 per cent stamping plant scrap
A	.088	.009	.013	.027
B	.012	.014	.022	.041
C	.01	.011	.017	.034
D	.009	.01	.016	.031

*In per cent based on all metal recovered from furnace.

Table II

GAS CONSUMPTION IN CUBIC FEET OF GAS REQUIRED TO MELT 1000 POUNDS OF ALUMINUM

Furnace	100 % virgin	70 virgin 30 mill scrap	100 % mill scrap	100 % stamping plant scrap
A	5100	5200	5600	5700
B	4500	4600	5100	5300
C	3000	3100	3300	3400
D	2500	2600	2800	2900

Table III

LABOR COSTS BASED ON EACH 1000 POUNDS OF ALUMINUM SLABS RECOVERED

Furnace	100 % virgin	70 % virgin 30 % mill scrap	100 % mill scrap	100 % stamping plant scrap
A	$1.70	$1.87	$1.87	$1.87
B	1.56	1.72	1.98	1.98
C	1.42	1.56	1.80	1.80
D	1.18	1.30	1.50	1.50

Table IV

ACTUAL TIME REQUIRED TO MELT SPECIFIED CHARGES

	100 per cent virgin		70 virgin 30 mill scrap		100 per cent mill scrap		100 per cent stamping plant scrap	
Furnace	Pounds	Min.	Pounds	Min.	Pounds	Min.	Pounds	Min.
A	300	65	300	65	300	65	300	65
B	425	36	400	36	350	36	350	36
C	650	28	625	28	525	28	525	28
D	1100	23	1000	23	850	23	850	23

NOTE: Mill scrap is composed of about 15 per cent plate scrap and about 85 per cent of baled scrap, all bright and clean, free from oil and foreign matter. This metal is baled into 6 x 7 x 13-inch bales. Stamping plant scrap varies from 12 to 22 gage, contains about 20 per cent spinnings and sometimes some foreign material such as bale wire and retinned steel handles. Stamping plant scrap is coated with oil.

permitted the crew to watch the gas mixture and the contents of furnace. The capacity was about 625 pounds of aluminum.

The drum of this furnace made a complete revolution every 10 minutes, and was driven by a 2-horsepower reversing motor. When the furnace was revolved, the intensely hot sides and top directly exposed to the flame became a hot hearth, which greatly reduced the melting period and amount of gas used per 100 pounds of aluminum. The revolving also served to thoroughly agitate the metal.

The ladle was preheated by the escaping gases from the pouring end of the furnace; these gases left the furnace at 1500 degrees Fahr. When the charge was poured, the ladle was supported by two arms secured to the furnace frame, and the metal ran directly into the ladle from the pouring spout. This was found to be an aid in reducing the blister loss.

These furnaces were not glazed. After they were run 24 hours, 6 days per week continuously, for 15 months, the linings wore down from 5½ inches to 2 inches. About 9000 heats were run in the 15-month period, and the linings then had to be replaced.

The advantages of this furnace are large volume, low gas and labor cost, and reasonable melting losses. The quick melting and rotating of the furnace seem to produce superior metal and the subsequent losses from blistered metal are less than normal. The furnace is comparatively free from breakdown troubles, although there is much room for improvement, the bearings being of especially poor design. A large amount of dross is blown out of the furnace and for rolling mill purposes it is necessary to place this furnace in a separate building.

Furnace types "A," "B," and "C" used air at from 10 to 14 ounces pressure, and about a 6 to 1 mix with gas. The air and gas were delivered through separate pipes and mixed by hand-regulated sliding valves.

Furnace Type "D"

The two furnaces of the "D" type are the same make and

design as the type "C" furnace, all dimensions being the same except the following:

1 The length of the melting chamber is 24 inches longer making a total length of 96 inches. This extension was made to increase the capacity to 1000 pounds of aluminum.
2 The speed of the revolving drum was one revolution in 4 minutes and 25 seconds.
3 A proportional mixer, having a capacity of 6000 cubic feet of gas per hour, using a 6 to 1 mixture at 24 ounces pressure and driven by a 5-horsepower, 3600-revolutions per minute motor was built in as part of the furnace.

This furnace was finally adopted as being the most satisfactory and economical of all furnaces used. Operating data are given in Tables I, II, III and IV. The form of melting report used is shown in the accompanying illustration.

General Furnace Practice

When the furnace was charged, 1 to 1 1/4 ounces of kryolite was added for each 100 pounds of aluminum. When the metal was melted, about 1/3 ounce of chloride of zinc per 100 pounds of aluminum was thrown into the furnace, taking care that the zinc was spread over the melt. The dross was immediately skimmed off and spread out on iron floor plates to cool. Later it was stored in the pit below the furnace.

The metal was poured at a temperature of 1225 to 1275 degrees Fahr. into cast iron ladles, about ½ teaspoonful of chloride of zinc having been put into each ladle just previous to filling. The ladles were skimmed before pouring the metal into slab molds.

With types "B," "C" and "D" furnaces, a reducing flame was used, as an oxidizing flame would have caused deterioration of the metal.

These four types of furnaces were operated 24 hours, 6 days per week. Accurate costs were kept on fuel, labor, and melting losses for each 8-hour shift. Artificial gas having a value of 600 B.t.u. per cubic foot, costing 51c per 1000 cubic feet was used.

The men were paid a poundage scale, based on pounds of rolling slabs recovered. The poundage rates were highest for the melting pots and lowest for the large size combination revolving and tilting type of open flame furnace. The head melter for each type of furnace was guaranteed 54c per hour; all helpers were guaranteed 45c per hour. In general the men averaged 20 per cent above the guaranteed hour rates.

Large amounts of aluminum castings and old aluminum sheet were melted, but since these were sold as remelt, and not used for rerolling, no data is presented covering this class of metal. Only virgin aluminum, mill and stamping plant scrap was used for casting into rolling slabs.

The methods of melting, pouring slabs, rolling, drawing etc. gave the writer an opportunity to make close observations on the virgin aluminum produced by the four domestic plants and 11 foreign plants. Great variations were found in aluminum ingot. Some plants produce uniformly good ingot. In others the product is variable in quality. Under the head of conclusions the writer lists some of his observations on aluminum ingot.

After about one year's experiments, the combination revolving and tilting type of open flame furnace was finally adopted for all melting operations. This method of melting aluminum and casting slabs was continued even after the plant was subsequently sold to the Aluminum Goods Mfg. Co. The same method was used by the writer in the new aluminum rolling mills built at La Grange, Ill. for the Aluminum Products Co. There are now four aluminum rolling mills using this method of casting slabs, with a combined capacity (24 hours, 310 days per year) of 32,000,000 pounds of rolling slabs.

Rolling Slabs

The book mold and the flat or open type mold were employed. In using book molds much time is wasted in securing and releasing the clamps. Also, since the slabs are cast vertically, a large shrink hole appears when the metal starts to freeze, and it is necessary to keep filling this hole with a small hand ladle. All impurities remain in the slab, and when rolled

into sheet, there is an occasional elongated pocket of dross in the center of slabs. There is generally a blister loss of 5 to 10 per cent with this type of slab mold, and the blisters occur on both sides of the sheet.

When flat molds are used the slab generally is 1¾ inches deep, 12 inches wide, and 18 inches long. The molds are open on the top and are placed in rows on an I-beam rack. Each slab weighs about 33 pounds. When the metal is poured into the mold it is immediately double skimmed to remove impurities. When rolled into sheet, there are no dross pockets. The blister loss is not more than 2 to 5 per cent with this type of slab, and the blisters occur on only one side of the sheet. The metal made in this type of mold is close grained, and when machined or polished, has a clear dense surface, free from any pores visible to the eye.

The book mold method of making slabs was discarded on account of the high labor costs and generally inferior metal. The merits of the flat slab have been fully set forth.

As it cools, the flat slab becomes slightly concave, due to shrinkage. A border about 3 inches wide appears around the entire outside edge of the slab as this outer edge cools more rapidly than the center. This border is smooth, and encloses a mottled center composed of varied shapes generally resembling a hexagon with three long and three short sides; sometimes these shapes appear more like triangles. In general, each batch of ingot has its own peculiar shrinkage shapes; this is not associated with varied melting practice, but is in the metal itself. The writer has noticed that ingots made by a small company in England produced a most distinctive slab, in that the shrink marks only occupied a small portion of the center and were about one third the usual size.

Shrinkage marks entirely disappear when given two passes through the hot mill. It takes seven passes to roll a slab of this particular size into a plate 24 inches wide by 1/8-inch thick. After hot rolling, the plate is still quite soft and can therefore be rerolled to 30 gage without reannealing.

Conclusions

The writer favors quick melting, preferably with a rotary furnace. The temperature of the furnace atmosphere should not exceed 1800 degrees Fahr. Temperatures exceeding this value result in rapid deterioration of the drawing qualities and cause excessive melting losses.

Blistered sheet is primarily associated with poor ingots, and secondarily with long melting periods at high temperature, poor furnace and slab skimming, and over annealing.

The drawing quality of the metal cannot be entirely judged by the analysis. However, silicon is most objectionable, and iron should not exceed ½ of 1 per cent. Copper, if higher than 1/3 of 1 per cent, tends to rapidly harden the sheet when rolled.

Discussion

E. A. ROEDELL.—A point of information. I would like to ask the speaker if he ever had any experience in mixing antimony with aluminum.

J. A. LANGE.—I have not had any experience in that. In the utensil industry we strive to sell pure aluminum. If we don't have pure aluminum it is hard to sell it. We buy the best metal we can possibly buy. We have even given up the 98 per cent metal and have gone to 99 per cent. We have also given up the use of manganese.

E. A. ROEDELL.—I had in mind what action antimony would have.

J. A. LANGE.—I am not familiar with that. I am only familiar with manganese and nickel.

E. A. ROEDELL.—I have found by adding nine to one that it will make it more pliable or give greater elongation.

J. A. LANGE.—Are you receiving a rolling slab or rolling a sheet out of that slab? What did you make your test on, a casting or a slab or a rolled sheet?

E. A. ROEDELL.—On a square bar. I twisted it the same as steel for reinforcement.

CHAIRMAN R. J. ANDERSON.—Mr. Lange has brought up a number of questions here, though the subject is not of intense interest to foundrymen.

Mr. Lange states on page 552 that "Slabs could be made continuously and rolled directly from the molds." I would regard rolling directly from the molds as exceedingly bad practice.

J. A. LANGE.—The Aluminum Co. of America is using that method. I have tried both. I believe the greatest danger in rolling directly from the molds is that it is hard to control the temperature of those slabs. I believe if the slabs can be run through a slab furnace the temperature can be controlled far more accurately and better results can be obtained. Taking a large furnace (I was using a revolving furnace) after pouring one thousand pounds of metal, which meant practically 30 slabs, when the last metal was being rolled the temperature had dropped about 300 degrees.

W. M. WEIL.—We have not performed any experiments in connection with rolling slabs but we have found that the use of fluor spar in the ladle has a tendency to eliminate the coarse grain in the alloys, and I think it would be interesting to perform similar experiments on the pure aluminum. I am inclined to believe it would have a similar effect. The use of fluor spar in the ladle in the case of alloys does change the grain to a finer and closer grain. Take coarse grain metal and treat it in that way and you will find a difference in the grain.

The other point I have to make is that I think it would be interesting to experiment with silicon alloys for use in sheets for tea kettles. We find that an alloy with a few per cent of silicon resists corrosion better than any other alloy we have found. Whether it is capable of being rolled and drawn we don't know. I think experiments along those lines would also be interesting. The aluminum with a small percentage of silicon does resist corrosion better provided the iron content is kept down to a minimum. We have not facilities for experimenting with rolling bars of that type, but I believe Mr. Lange will find if he goes ahead with experiments along those

lines, that he might be able to bring in some interesting data next year.

CHAIRMAN R. J. ANDERSON.—That will be interesting indeed, I might point out, in connection with your remarks, that such alloys have actually been rolled up to 11 per cent silicon in Germany, in sheet.

Aluminum and Aluminum-Alloy Melting Furnaces

By Robert J. Anderson, Pittsburgh

In connection with its work during the past 10 years in the prevention of waste in the mining, mineral, and metallurgical industries of the United States, the Bureau of Mines has carried out numerous investigations looking to the more efficient utilization of natural resources. In its preliminary investigations, it soon became apparent that there were large losses involved in the melting and production of the nonferrous metals and alloys; metal, fuel, and casting losses are included here. The investigation carried out by Gillett and reported in *Bulletin 73* showed that the metal and fuel losses involved in brass practice amounted to about $4,000,000 per annum. It also was shown in this investigation that, if the losses incurred in the average practice were reduced to those of the best practice, about $2,000,000 could be saved annually. In another investigation reported in *Bulletin* 108, it was shown that the losses in melting aluminum-alloy borings, owing to poor recoveries on smelting, amounted to about $300,000 per annum. In a recent investigation of casting losses in the production of light aluminum-alloy sand castings, it was shown that the annual loss amounted to about $1,200,000. If these casting losses were reduced 50 per cent by eliminating the occurrence of readily avoidable defects, then a saving of $600,000 would accrue.

The preliminary investigations which had been carried out by the Bureau of Mines in the metallurgy of aluminum indicated that serious losses exist in the melting of aluminum and its light alloys. Both metal and fuel losses are large. Accordingly, it was decided to make a thorough study of the subject, and to that end the co-operation of the industry was enlisted. The detailed results of the investigation made will appear later in a bulletin prepared by the author, entitled Alu-

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minum and Aluminum-Alloy Melting Practice in the United States. The object of the present paper is to discuss briefly the various types of furnaces used commercially in the United States for melting aluminum and its light alloys. Some general information bearing upon the selection of furnaces will be given also.

Magnitude of The Aluminum Industry

The aluminum industry has grown so rapidly since the time when the metal became relatively cheap—about 1890—that its importance cannot be appreciated other than by comparison with the other major nonferrous metals. Aluminum now stands fourth in output among the nonferrous metals, being surpassed by copper, zinc, and lead. It has been suggested by the late Prof. J. W. Richards that the world's production of aluminum will exceed that of lead by 1930 and of zinc by 1940. Whether this will transpire is problematical, but the rapidity with which the domestic industry has grown in the past 10 years has been most striking. Using the production figures for 1918, which was the year of greatest output, the world's production of aluminum was placed at 489,000,000 pounds of which 225,000,000 pounds were produced in the United States. The recovery of secondary aluminum as such or in the form of alloys in 1918 amounted to 30,100,000 pounds. It may be stated here that all aluminum is melted at least twice and most of it several times, considering a unit weight of metal. All primary aluminum from the reduction cells is remelted and cast into pigs or into rolling ingots or remelted for alloying in the preparation of primary aluminum alloys. Primary aluminum pig is remelted for casting into ingots in rolling-mill practice or remelted for the manufacture of alloys in the foundry. It may be stated conservatively that, for the purposes of this paper, all primary and secondary aluminum may be considered to be melted at least twice, and there is a melting loss each time.

In distinguishing between aluminum-melting practice and aluminum-alloy melting practice, it is necessary to point out that about 50 per cent of the domestic consumption of aluminum

is used as such while the remainder is employed in the manufacture of light aluminum alloys.

Metal and Fuel Losses In Melting Aluminum and Its Light Alloys

The loss of metal due to oxidation, (the so-called dross loss) on melting aluminum and its light alloys is large. On the basis of data reported by operating companies and of figures derived from actual tests and from other sources, the gross loss of metal resulting on remelting substantially pure aluminum may be taken as not less than 2 per cent, although extreme figures of 0.75 and 5 per cent have been reported. This refers to the remelting of aluminum for casting into ingots, but it may be taken as an average figure for the gross melting loss for aluminum in general. The average net loss resulting on remelting substantially pure aluminum may be taken as not less than 1.25 per cent on the basis of reported figures, allowing for the recovery of mechanically entangled metal from the dross. If dross be considered to contain 40 per cent metallics on the average, the net loss on this basis (derived from the gross loss) would be 1.2 per cent; this agrees well with the figure given just above. If it be considered that the metal is melted at least twice, then the average net loss of 1.25 per cent is equivalent to 2.5 per cent for all the aluminum used as such.

In the same way, the gross loss of metal resulting in melting for the production of alloys in foundry practice may be taken as 4 per cent on the basis of reported figures, although extremes of 1 and 8 per cent have been given. This refers to melting in a variety of furnaces. The average net loss in the melting of alloys in foundry practice may be taken as 2.5 per cent, on the basis of reported figures. If the dross be considered to contain 40 per cent metallics on the average, the net loss on this basis would be 3 per cent; this does not agree well with the figures just given. The figure of 2.5 per cent for the net loss will be used here. If it is considered that the metal is melted twice, then the average loss of 2.5 per cent is equivalent to 5 per cent on the gross melt.

In regard to the fuel losses incurred in melting aluminum and its light alloys, the data which have been made available through the present study, while not all that could be desired, have been sufficient to indicate low fuel efficiencies on the average. It can be shown by detailed calculations that if all the available heat units in a fuel were utilized, that is, if the furnaces operated at 100 per cent efficiency, it would require the following amounts of different fuels to melt 100 pounds of aluminum and superheat it to 800 degrees Cent. for pouring: Approximately 4 pounds of coal or coke; 2.7 pounds or 0.35 gallons of fuel oil; 57 cubic feet of natural gas; 86 cubic feet of illuminating (city) gas; and other fuels in proportionate amounts. The fuel consumption in melting aluminum and aluminum alloys is considerably greater than in melting brass and bronze, as may be shown by a comparison of the preceding figures with those for brass in general. Thus, H. W. Gillett in Bureau of Mines bulletin 73, 1916, has given the following figures for the amounts of different fuels required to heat 100 pounds of brass to the pouring temperature: About 2 pounds of coal or coke; 1.4 pounds or 0.18 gallon of fuel oil; 26 cubic feet of natural gas; 41.5 cubic feet of city gas; and 217 cubic feet of producer gas. The actual limits as to fuel consumption as reported by various plants during the present investigation were as follows: 50 to 200 pounds of coal or coke; 0.54 to 15 gallons of oil, and 150 to 1000 cubic feet of natural gas or artificial gas. In practically all instances, it was found that tremendous amounts of fuel were being consumed and that the furnace efficiencies were extremely low. It is doubtful that the average fuel efficiency in aluminum and aluminum-alloy melting furnaces can be more than 5 per cent of the theoretical.

Monetary Values of the Losses in Melting

Turning now to the question of the monetary losses incurred in aluminum and aluminum-alloy melting practice, figures have been derived for these values as applied to commercial practice in the United States. Reverting to the data given above as to the net losses incurred, it was stated that

these were 2.5 per cent for aluminum and 5 per cent for the light alloys, on the gross melt. The following figures may be considered:

	Pounds
Total consumption of primary aluminum	225,000,000
Total aluminum used as such	112,500,000
Total aluminum used for alloys	112,500,000
Net loss (2.5 per cent) in melting aluminum	2,812,500
Net loss (5 per cent) in melting aluminum alloy	5,625,000
Total loss	8,437,500

Allowing for extra meltings and the melting of borings, drosses, and other scraps, it may be considered that the net loss is about 9,000,000 pounds of aluminum per annum. On the basis of a $0.33 metal market, the total monetary loss may be placed at $2,970,000 per annum. Setting aside any consideration of the additional losses on melting owing to furnace inefficiencies, overhead, and labor charges, it is evident that, if the present net losses could be reduced 50 per cent, then a saving of about $1,500,000 per annum would accrue. Probably, $2,000,000 per annum could be saved if the fuel and other losses were considered on the basis of similar improvements. However the calculations be made, it is certain that if the average practice were raised to the standard of the best practice very great savings, at least of the order of those just given, could be effected.

Types of Furnaces Used Industrially

The problems involved in melting metals and alloys are complex, and as a whole the subject is often more difficult of investigation and treatment than problems of a purely scientific character. At the present time, the selection of the correct type of furnace for a given set of operating conditions is made especially difficult by the multitude of different types of furnaces extant and more particularly by the lack of comparable data regarding each one. Also, the selection of a furnace must be governed by the requirements of the plant, and it is not possible to state that there is any one best furnace. T. H. A. Eastick in *The Metal Industry* has enumerated a number of factors which govern the kind of furnace to be installed for brass melting, and these will bear repetition here. The fac-

tors are: (1) the metal or alloy to be melted, its melting point and casting temperature; (2) the number of different alloys in use and the production of each per day; (3) importance of the possible contamination of one alloy by another; (4) kind of scrap used, its character, size, and shape; (5) foundry or other practice; (6) continuous or intermittent operation; (7) size and weight of the castings made; (8) physical characteristics of the shop and the neighborhood where the work is done; (9) kind of fuel in use in quantity for other furnaces in the plant; and (10) accessibility to coal, gas, oil, and electric power. This list might be extended considerably, but a sufficient number of items have been given to indicate the necessity for carefully studying all requirements and conditions before installing any melting equipment.

Referring especially to melting furnaces for aluminum alloys, it may be said broadly that in foundry work the practice has followed along the general lines of brass melting, probably because aluminum alloys have been cast largely, in the past, in brass foundries. Light aluminum alloys are, or have been, melted in practically all types of furnaces used for brass and bronze; the iron-pot furnace, so widely used for the melting of so-called white metals, is the only furnace employed for aluminum alloys, that is not used for brass and bronze. Actually, a great variety of types of furnaces are in commercial use for melting aluminum and its light alloys, and, broadly speaking, these can be said to be no thoroughly standardized mode. The reason for this is not hard to find. The aluminum industry is relatively you g, and commercial melting methods are in the course of development. The type of furnace employed depends upon whether aluminum or one of its light alloys is being melted, as well as whether, in the case of aluminum, the metal is melted simply for re-pigging or for casting into rolling ingots, and, in the case of the light alloys, whether they are to be poured into sand castings or used for the production of die- or permanent-mold castings or are poured into rolling ingots. The smelting of aluminum-alloy borings and related aluminum-bearing scraps presents a distinct prob-

lem, and various types of furnaces are used for this purpose.

Furnaces In Rolling-Mill Practice

When speaking of furnaces for melting aluminum, it will be generally understood here to refer to melting prior to casting into rolling ingots, although, of course, all direct metal from the reduction cell is remelted and either cast into rolling ingots or poured into pigs. Various types of furnaces have been

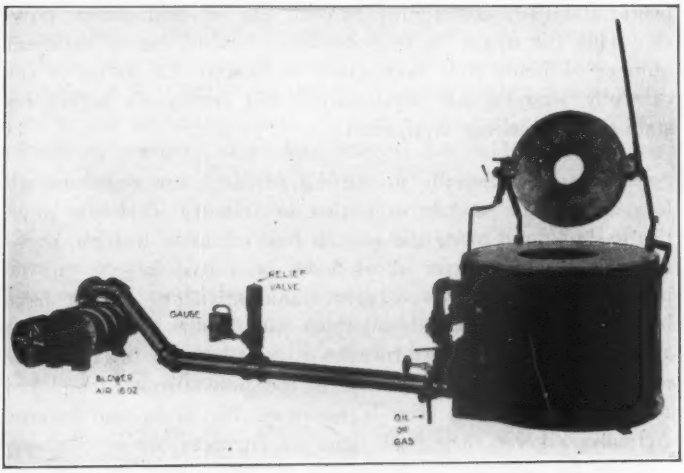

FIG. 1—MONARCH-TYPE STATIONARY CRUCIBLE FURNACE

employed for remelting the reduction-cell metal, but, in the United States, open-flame reverberatory type furnaces, fired by coal, oil, or gas, appear to have been employed principally. A large rectangular Baily-type electric furnace was once used by the Aluminum Co. of America at its Massena, N. Y. plant for this purpose. For melting substantially pure aluminum prior to casting into ingots for rolling or other working, reverberatory-type furnaces are largely employed in the United States, England, Japan, and on the continent. In the United States, the coal-fired reverberatory furnace appears to have been

used principally, but, in more recent years, gas and oil have been used as the fuel in these furnaces.

More recently, rotating open-flame gas- and oil-fired furnaces have found favor in some small rolling mills for aluminum melting. The employment of the reverberatory-type furnace in rolling-mill work has been found necessary because large capacity is required and further because continuous melting is desirable. The question of the fuel selected has been decided, in some installations, on the basis of actual fuel costs and availability, while in others it appears that coal has been employed arbitrarily with little thought of its applicability. The use of gas-fired reverberatory furnaces in rolling-mill practice has been described by the author in *Chemical and Metallurgical Engineering*. The use of the Baily-type electric furnace for melting aluminum has also been described in the same journal by D. D. Miller. For melting aluminum alloys which are to be rolled, the reverberatory furnace is generally preferred, but crucible melting has also been employed.

Furnaces In Foundry Practice

The greatest variety of types of furnaces is employed in foundry practice for melting light aluminum alloys. Thus, the following types of furnaces are at present in daily use in the aluminum foundries of the United States: Coal, coke, oil and gas-fired reverberatory furnaces; oil and gas-fired stationary and tilting iron-pot furnaces; coal and coke-fired natural and forced draft pit furnaces, using a crucible; oil and gas-fired stationary and tilting crucible furnaces; oil and gas-fired, open-flame tilting, rotating, and stationary furnaces; and electric furnaces of various types. The stationary and tilting iron-pot furnaces are favored in the United States, particularly by large foundries, but open-flame furnaces are being used more widely now than a few years ago. In small foundries, and in foundries where only a minor part of the output is in light aluminum alloys, pit or crucible furnaces are used largely. Electric furnaces for melting light aluminum alloys are just now receiving considerable attention, and a few installations have been made.

The tendency toward the employment of furnaces of large capacity, such as reverberatory furnaces, open-flame barrel-shaped furnaces, and electric furnaces, has been quite marked in recent years and has come about through the enlargement of plant capacity. Where a foundry is turning out 5,000,000 to 25,000,000 pounds of finished castings per year, melting in units of small capacity requires many furnaces. One of the commercial open-flame barrel-shaped furnaces can melt at least one ton of metal per hour, and the advantage of operating units larger than crucibles or iron pots is apparent in foundries where the daily output amounts to thousands of pounds. Description of most of the types of furnaces which are used in foundry practice have appeared in the technical press, and some detailed data with regard to their performance will be given later in this paper.

Furnaces in Die-Casting and in Permanent-Mold Casting Practice

In modern aluminum alloy die-casting practice, the alloys are melted in small cast-iron melting pots which may be considered part of the die-casting machine proper. The fuel usually is gas. In both die-casting and in permanent-mold casting work, it is standard practice to make up the alloys in an alloying furnace and run them into small pigs. The prepared alloys are then delivered to the die-casting machine for remelting. Stationary iron-pot furnaces are preferred for alloying in the United States, although several other types have been employed. In the case of permanent-mold casting practice, small iron pots fired by gas are preferred for melting the alloys prior to casting.

Furnaces For Smelting And Refining

In the case of smelting and refining furnaces for aluminum and light aluminum alloy borings, scraps, and drosses, the domestic practice is not standardized, and many different types of furnaces are employed commercially. For smelting borings and other light scraps for the production of so-called "casting aluminum," and in making secondary aluminum and aluminum alloys, stationary iron-pot furnaces, reverberatory furnaces, pit fur-

naces, and open-flame tilting and rotating furnaces are employed. Strictly speaking, furnaces that are used for running down borings, drosses and other high aluminum-bearing scraps should not be called "refining" furnaces, since no actual refining of the materials is accomplished.

The primary object in smelting aluminum and aluminum-alloy scraps may be two-fold; (1) simple remelting for the purpose of pigging clean choice scrap; and (2) obtaining high recoveries on dirty borings and poor grade scraps. The furnace to be employed should be governed by the kind of material smelted—at least to a certain extent.

Furnaces For Making Intermediate Alloys

Intermediate copper-aluminum alloys and other so-called hardeners for use in foundry practice have been made in various types of furnaces. Generally speaking, the stationary iron-pot furnace is preferred for melting the aluminum in the manufacture of say 50:50 copper-aluminum alloy, the copper being melted either in pit or in crucible furnaces. Of course, furnaces other than the iron-pot type are used for melting the aluminum in the preparation of these alloys. In cases where intermediate alloys are made of aluminum and a metal of very high melting point, such as nickel, cobalt, or manganese, an electric furnace may be advantageously employed. A small Rennerfelt-type electric furnace has been employed commercially for this purpose. The Detroit-type rocking electric furnace has been used for melting aluminum bronze turnings to which aluminum was subsequently added for the manufacture of 50:50 copper-aluminum alloy.

The type of furnace employed depends, of course, largely upon the personal choice of different foundrymen and the amount of metal to be melted. Taking the cases of 60 representative plants reporting to the Bureau of Mines, 16 reported the use of stationary iron-pot furnaces, while two used tilting iron-pot furnaces. Two used tilting crucible furnaces, and 19 employed stationary crucible furnaces. Pit furnaces were reported in operation at the largest number of plants, 29 such installations being stated as in use, but it is to be remembered

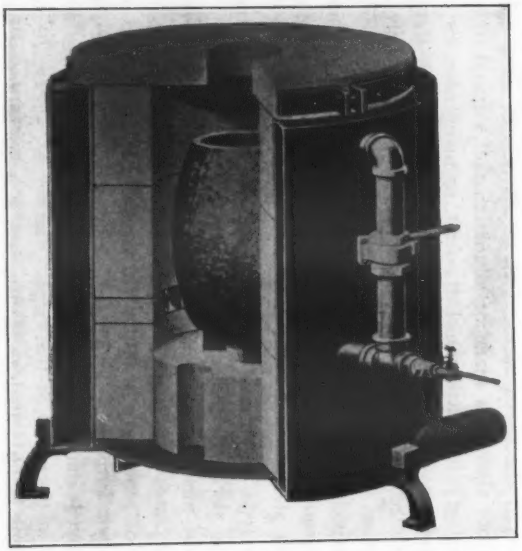

FIG. 2—CAWARD-GASKILL TYPE STATIONARY CRUCIBLE FURNACE

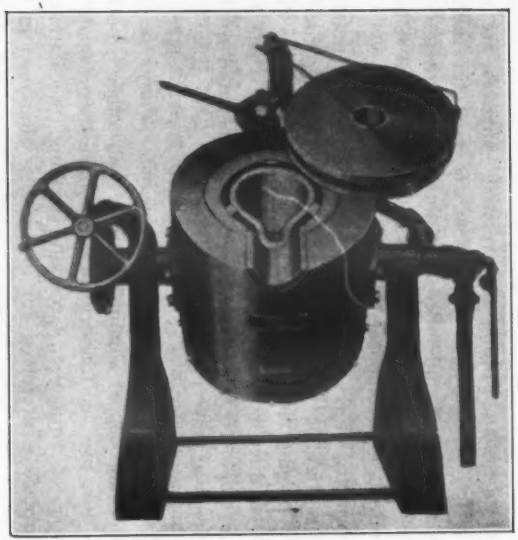

FIG. 3—WAYNE-TYPE TILTING CRUCIBLE FURNACE USING FUEL OIL

that this type of furnace is generally used in jobbing shops and in small foundries devoted principally to brass and bronze. Six plants reported the use of pear-shaped open-flame tilting furnaces, and one plant the use of a barrel-shaped, open-flame furnace. The use of reverberatory furnaces was reported by three plants, and three plants reported the use of electric furnaces of different types. The foregoing remarks refer especially to furnaces for foundry work. Omitting here the pit furnaces, where a plumbago crucible is used for melting, it may be said, on the basis of the information furnished that the stationary iron-pot furnace and the stationary crucible furnace are the most favored types for melting light aluminum alloys.

Pit Furnaces

Aluminum alloys are still melted in the usual types of brass pit furnaces, particularly in foundries devoted principally to brass and bronze. Under some classifications, there are included under pit furnaces all kinds of furnaces, irrespective of the fuel employed, where only a single crucible is used in the furnace, where the melting is done in the crucible and that crucible is used for pouring the metal. Natural-draft and forced-draft coke and coal furnaces are usually built in an actual pit below the floor level; so-called pit furnaces, fired by oil or gas, usually are not, although they may be. The latter are generally referred to as crucible furnaces in contradistinction to actual pit furnaces fired by coal or coke, and they are so referred to in this paper.

An idea of the construction of pit furnaces can be given in a few words. In the case of natural-draft pit furnaces, fired by coal or coke, a usual form of construction consists of a pit about 6 to 8 feet wide and the same depth and of varying length depending upon the number of furnaces. The pit is ordinarily divided in two, about half the width being used for the setting of the furnace and the remainder for the runway which is used for removing ashes. The latter is covered either with an iron grating or with iron plates. The individual furnaces are built side by side in the pit and sup-

ported on steel girders set about 3 to 4 feet down in the pit. Grate bars, which are usually hinged, make up the bottom of the individual furnaces. Any fuel or ash on the grate bars may be dropped into the pit below by control chains which run to the floor above. At the rear of each furnace, there is a square rectangular flue which leads to a larger flue at the back of the whole battery, and this in turn leads to the stack. In melting, the crucible is set on the fuel previously placed on the grate bars, and additional fuel is placed around the sides of the crucible. Each hole, is covered with some kind of a cover, usually a dome- or flat-shaped cover which may be swung aside or otherwise readily removed. The construction of pit furnaces using forced draft is substantially the same as that of the natural-draft furnace, but the ash pit is enclosed so that air may be forced into it instead of being open to the air.

In American practice, pit furnaces are in use in foundry practice for melting aluminum alloys, taking from Nos. 40 to 400 crucibles, although Nos. 60 and 80 are the most common sizes. The two latter hold about 60 and 80 pounds of No. 12 alloy, respectively. These furnaces are lined generally with a 4-inch thick lining of good grade fire brick. Most pit furnaces are fired by coke, although both bituminous and anthracite coal are used, and natural draft is most frequently employed. In actual commercial installations, from one to eight furnaces are handled per furnace tender, and from 37 to 900 pounds of metal are melted per hour, as reported. The fuel consumption in pit furnaces is very variable, reported figures varying from 50 to 200 pounds of coal or coke per 100 pounds of alloy, equivalent to furnace efficiencies of from 2.3 to 8 per cent. In general, the fuel efficiency of the pit furnace is quite low. Melting costs for fuel in these furnaces may be taken as ranging from $0.16 to $0.55 per 100 pounds of metal melted, with coke at $6.50 per ton. As reported to the Bureau of Mines, from one to six heats are taken from pit furnaces per day, and the melting period varies from 30 minutes to two hours, depending upon the size of the charge. This is equivalent to a melting time of from one to four hours

per 100 pounds of alloy. Roughly, a pit furnace, fired by coke, should give at least six heats of 100 pounds per 9-hour day with an average melting period of 75 minutes.

The life of linings in pit furnaces varies from four to 24 months, equivalent to 400 to 1,800 heats, with an indicated average of 1000 heats. The life of crucibles in pit furnaces varies from 28 to 100 heats as reported, with an indicated average of 42 heats, equivalent to about 2,500 pounds of metal. The gross melting loss in pit furnaces varies from 2 to 3 per cent, as reported, with an indicated average of 2.3 per cent. The net melting loss, assuming recovery from dross and skims, may be taken as about 1.4 per cent. On the whole, pit furnaces may be regarded as fairly satisfactory for melting aluminum alloys from the standpoint of melting losses, but they are slow in operation, troublesome to handle, and exceedingly inefficient as to fuel. Taken by and large, the pit furnace is not a suitable furnace for aluminum-alloy melting in foundry practice, in the opinion of the author.

Stationary Crucible Furnaces

Stationary crucible furnaces are used to a considerable extent for melting light aluminum alloys in foundry practice. They are fired by oil or gas. In distinguishing between pit furnaces, using a crucible for melting, and stationary crucible furnaces, for the purposes of this paper, there are included here, under the latter, all furnaces where a plumbago crucible is set in a furnace made by lining an iron shell with refractory material. The shell may be set down partially in a pit, or it may be above the level of the floor; usually it is above the level of the floor and built as a separate unit. The capacity of the usual stationary crucible furnace is small. These furnaces are built to take up to No. 600 crucibles, but Nos. 60 to 100, with capacities of from about 60 to 100 pounds of No. 12 alloy are the most common sizes. The general principles that govern the most economical size of crucibles, as laid down by Gillet for brass melting, apply in the melting of light aluminum alloys. Crucible furnaces are run on intermittent heats, and

usually the melting crucible is employed also for pouring. After the charge is melted, the crucible is lifted out of the furnace and taken to the molds, and the metal is there poured. In stationary crucible melting there is ample opportunity for the products of combustion to come into contact with the alloy during melting, and contamination from the products of combustion may occur that would not be possible in iron-pot melting.

In the ordinary stationary crucible furnace, the crucible is heated over its exterior surface by the combustion of the fuel, and the waste gases are discharged through a hole in the furnace cover. The flames are projected into the furnace tangentially so that they are given a rotary and upward motion around the crucible, and the incandescent gases are in intimate contact with the alloy during melting. The design of the usual stationary crucible furnace is extremely simple. The ordinary furnace consists simply of a sheet steel shell, cylindrical in shape, lined with refractory fire brick. One burner, set near the bottom of the furnace and leading into the interior through a hole in the shell and lining, is employed ordinarily. The melting crucible is set on a refractory block or stool placed on the bottom of the furnace. The details of design vary considerably among different furnace makers. Some stationary crucible furnaces are built with grate bars below so as to take solid fuel, but this type is not employed to any extent for melting light aluminum alloys. Fig. 1 shows the Monarch-type stationary crucible furnace, while Fig. 2 shows the construction of the Caward-Gaskill stationary-type crucible furnace.

In American practice, stationary crucible furnaces are generally small units, and such furnaces are installed usually in foundries of small output as single units. They are rarely run in a battery in aluminum-alloy foundry practice. The capacities are greatly variable, Nos. 25 to 150 crucibles being reported, of which the most common sizes are Nos. 60 and 90. These furnaces are lined generally with a 4-inch lining inside the furnace shell. Cast-iron, fire brick, and molded-clay covers are used on crucible furnaces, the last two having generally a hole

in the center for the escape of the combustion products. Both oil and gas are used for fuels in these furnaces, oil being the more common. Details of the burners used and the air supply cannot be gone into here, but, briefly, most of the commercial furnaces use low-pressure air. In actual installations, from one to three furnaces are handled per furnace tender, and from 110 to 200 pounds of metal are melted per hour, as reported. The fuel consumption in stationary crucible furnaces is variable, reported figures varying from 0.54 to 15 gallons of fuel oil per 100 pounds of alloy, equivalent to furnace efficiencies of from 2.3 to 64.8 per cent. On the whole, the fuel efficiency in stationary crucible furnaces is low, and the exceptionally high efficiency reported is open to question. As a rule, on the basis of reported figures, the fuel consumption in these furnaces will vary from 10 to 15 gallons of oil per 100 pounds of No. 12 alloy, with an average melting cost for fuel of $1.

From five to 12 heats per nine-hour day are taken from stationary crucible furnaces in practice, and the melting period varies from 30 minutes to one hour, depending upon the size of the charge. This is equivalent to a melting time of from 45 minutes to three hours per 100 pounds of charge. Roughly, a stationary crucible furnace, fired by oil, using a No. 100 crucible taking about 100 pounds of alloy, should give at least seven heats per nine-hour day, with an average melting period of about one hour. The life of linings in stationary crucible furnaces varies from three months to two years, equivalent to 150 to 9,000 heats, with an indicated average of 3,000 heats. The life of crucibles in stationary crucible furnaces varies from 18 to 100 heats, as reported, with an indicated average of 49 heats, equivalent to about 2,900 pounds of metal melted. The gross melting loss in these furnaces varies from 1 to 6 per cent, as reported, with an indicated average of 3.6 per cent. The net melting loss may be placed at 2 per cent. On the whole, crucible furnaces, both stationary and tilting, may be regarded as fairly suitable for melting light aluminum alloys in foundry

practice, for some purposes, but they are quite inefficient as to fuel, and the melting losses are rather high.

Tilting Crucible Furnaces

Tilting crucible furnaces are used to a small extent for melting light aluminum alloys in foundry practice; they are fired usually with oil or gas. In distinguishing between tilting crucible furnaces and tilting iron-pot furnaces, both types

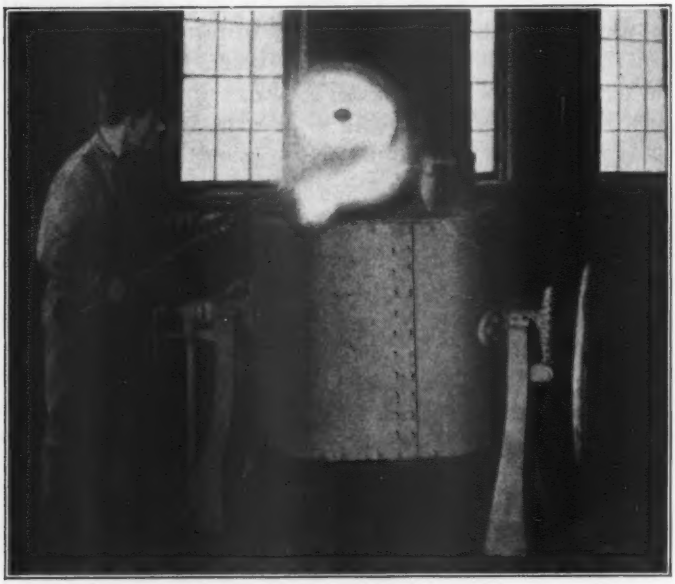

FIG. 4—ROCKWELL-TYPE SINGLE CHAMBER TILTING CRUCIBLE FURNACE

are similar in design, but in the former a plumbago crucible with a molded pouring lip is used. The tilting crucible furnace consists of an iron shell lined with refractory material; it is set on trunnions and fitted with the necessary tilting mechanism. The small units employed for melting aluminum alloys are always tilted by hand. The crucible is suspended from the top of the furnace so that it hangs down in the interior, and

the crucible is heated over its exterior surface by combustion of the fuel. Tilting crucible furnaces are built by a number of makers, but the general features of design are about the same.

The capacity of the usual tilting crucible furnace is small, a No. 80 crucible being used considerably in foundry practice. These furnaces are built in various sizes to take up to No. 600 crucibles, but extreme sizes, either large or small, are not used commercially. Tilting crucible furnaces are generally run on intermittent heats, although the practice of using a molten heel may be followed. When a charge is melted, it is poured into ladles or pouring crucibles for casting into molds.

The products of combustion may, or may not, have an opportunity to come into contact with the alloy during melting, depending upon the design of the furnace. Generally speaking however, there is more or less opportunity for the combustion products to pass over the surface of the liquid alloy during melting; this can be eliminated, on the other hand, by changing the design. In most tilting crucible furnaces, the products of combustion are discharged from a broken annular ring around the top of the crucible and thence through the hole in the furnace cover. If the waste gases were led out through a vent in the side of the furnace, the possibility of gases coming in contact with the alloy would be prevented. The method of firing both in crucible furnaces and in iron-pot furnaces is generally the same when gas or oil is used. Some of the tilting crucible furnaces put upon the market by furnace makers are built in quite large sizes—to hold up to about 1,000 pounds of No. 12 alloy, but these large furnaces are not used commercially for aluminum alloys. The details of the construction of tilting crucible furnaces are essentially the same as for stationary crucible furnaces. Tilting crucible furnaces using solid fuel have been employed for melting light aluminum alloys in foundry practice, but only to a small extent. Fig. 3 shows the Wayne-type tilting crucible furnace; Fig. 4 shows the Rockwell-type furnace, and Fig. 5 the Caward-Gaskill tilting crucible furnace.

Scant data are available as to the performance of tilting crucible furnaces on aluminum alloys under foundry operating conditions, but in general the data given above as to stationary crucible furnaces apply here.

Stationary Iron-Pot Furnaces

As has been mentioned, stationary iron-pot furnaces are favored considerably for melting light aluminum alloys in

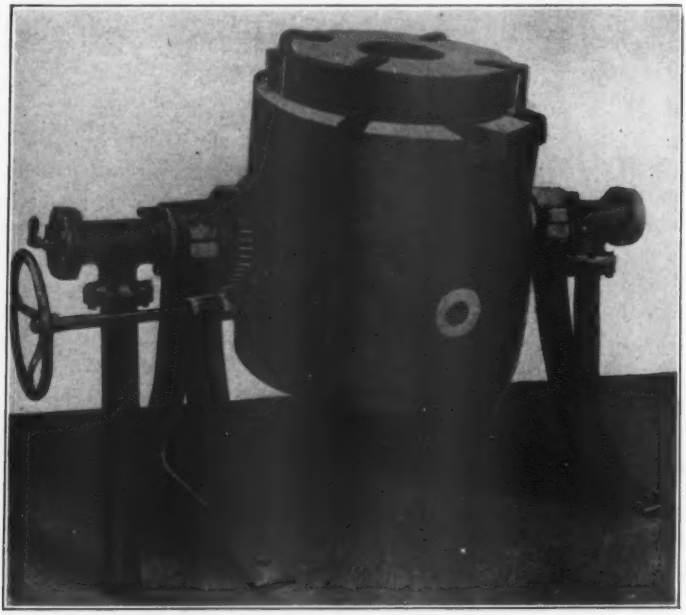

FIG. 5—CAWARD-GASKILL-TYPE TILTING CRUCIBLE FURNACE

foundry practice. These furnaces may be run as separate units or as a battery of more than one pot to a furnace; the practice of employing two or three pots to a furnace has several advantages. Oil or gas are generally used for the fuel. At the present time, stationary iron-pot furnaces are run without covers in most foundries, although some foundrymen are still

strongly disposed to use solid cast iron covers on small units. Stationary iron-pot furnaces are built in various capacities up to 400 pounds of No. 12 alloy, and 250 pounds is a common size. The pots may be either round or rectangular in shape, but they are usually round. In the stationary iron-pot furnace, the pot is heated over its exterior surface by the combustion of fuel in the space between the furnace walls and the pot. Normally, the products of combustion do not have an opportunity to come into contact with the alloy during melting. Ordinarily, a liquid heel of 50 to 150 pounds of alloy is left in the pot so as to to conserve the heat and also to facilitate alloying, and additional cold metal is charged to the heel after drawing a heat. When a charge is melted, the alloy is ladled out of the pot and poured.

Stationary iron-pot furnaces are manufactured by a number of furnace makers, and in some foundries they are built by mechanics in the plants. In the case of single units, the furnace consists of a round, square, or rectangular steel shell, lined with refractory brick, and the top is covered with a sheet steel roof lined with refractory material, with a hole in the center for setting the pot. The latter is hung from the top of the furnace and may be supported by wedge-shaped bricks at the center or a refractory stool beneath. One burner is used in single units. The burner should be so placed that the flames are not projected directly against the pot but rather around it, and the products of combustion are discharged through a small vent at the rear near the top. In some installations, the products of combustion are discharged through the flue directly into the air, while in others, the small vent leads to a large connecting flue, as in pit furnaces, and thence to a stack. With one furnace, a small stack may be connected directly to the vent. In the case of installations where two or more pots are placed in a furnace, a burner is used at each end. The pots are charged so that the burners are used alternately. Thus, in the case of a two-pot furnace with a charge of liquid metal in one pot and of cold metal in the second pot, the first burner nearest the first pot would be operating, and the second

FIG. 6—INSTALLATION OF SINGLE UNIT STATIONARY IRON POT FURNACES

pot would be preheated by the hot gases. After pouring the first pot, it would be charged with cold metal, the first burner turned off and the second one started.

This principle is employed in some double chamber tilting crucible furnaces and in double chamber tilting open-flame furnaces. At the present time, the iron-pot furnace (stationary and tilting) is the most extensively employed for melting in foundry practice from the standpoint of tonnage turned out.

In the United States, the capacity of stationary iron-pot furnaces varies from 100 to 400 pounds of No. 12 alloy in the case of circular pots, and from 600 to 1,200 pounds for the rectangular pots. The circular pot holding 300 pounds of alloy is a common size; this may be bowl-shaped, 18 inches in diameter by 18 inches deep. A typical rectangular pot is one 16 inches wide by 37 inches long by 26 inches deep; this holds from 1,000 to 1,200 pounds of alloy. Iron-pot furnaces of the stationary type are lined usually with a 4-inch thick lining of fire brick, although silica brick, carborundum fire sand, and commercial high temperature cements are used in practice. Covers are generally used on single unit iron-pot furnaces; such covers are simply dome-shaped covers made of cast iron about 1 inch thick. In large installations of these furnaces, covers are not employed usually. Oil is the preferred fuel for use in iron-pot furnaces; natural gas is used to a less extent, while illuminating (city) gas and blue water gas are employed in a few installations. Details of the burner equipment and air supply for iron-pot furnaces of the stationary type cannot be included here, but a typical installation may be cited: Pressure of air at the burner, 1.5 to 2 pounds; pressure of oil at the burner, 25 to 30 pounds; Anthony burner.

From one to eight furnaces are handled per furnace tender in practice, and from 100 to 2,400 pounds of alloy per hour are melted, as reported. The fuel consumption in these furnaces is very variable, reported figures varying from 1.25 to 5 gallons of oil per 100 pounds of alloy, and from 150 to 1,000 cubic feet of natural gas, equivalent to furnace efficiencies of from 5.7 to 57.3 per cent. In general the average fuel effi-

ciency in these furnaces is higher than in pit or crucible furnaces. Melting costs for fuel in iron-pot furnaces of the stationary type, using oil, vary from $0.10 to $0.40 per 100 pounds of alloy. From three to 10 heats are taken per day, and the melting period varies from 45 minutes to three hours, depending upon the size of the charge. This is equivalent to a melting time of from 12 minutes to one hour per 100 pounds of alloy. Roughly, it may be said that at least seven 300-pound heats should be obtained per furnace per nine-hour day, with an average melting period of 1.25 hours. A molten heel is used generally in iron-pot furnace practice, where it is generally recognized as advantageous. In the majority of plants, a heel of 50 to 100 pounds will be retained in the furnace after drawing a heat, and cold metal is charged to the heel.

The life of linings in stationary iron-pot furnaces is variable, from three to 12 months being reported. This is equivalent to from 225 to 1,300 heats, with an indicated average of six months and about 1,000 heats. The life of iron pots varies from 24 to 80 heats, as reported, with an indicated average of 47 heats, equivalent to about 14,000 pounds of metal for a 300-pound pot. The gross melting loss in these furnaces varies from 2 to 6 per cent, with an indicated average of 4.2 per cent. This is equivalent to a net melting loss of 2.5 per cent. Iron-pot furnaces may be regarded as fairly satisfactory for melting aluminum alloys in foundry practice, particularly where the output is fairly large. They are easy to handle and the labor cost for melting should be low. In actual practice, they are seen to be more efficient as to fuel consumption than pit or crucible furnaces although the melting losses appear to be higher.

Fig. 6 shows an installation of single unit stationary iron-pot furnaces in a large foundry.

Tilting Iron-Pot Furnaces

Tilting iron-pot furnaces, as used in foundry practice for melting light aluminum alloys, are usually fired by oil or gas. One installation where coke is used for the fuel has come to

the attention of the author, but this is to be replaced by an electric furnace. Tilting iron-pot furnaces are invariably operated as single units, and their general construction is similar to that of the stationary iron-pot furnace. A cast-iron pot is mounted in a furnace shell, and the pot is heated over its exterior surface by combustion of the fuel. As a rule, the capacity of the tilting furnace is larger than that of the stationary furnace using circular pots. Thus, furnaces with capacities of up to 600 pounds of No. 12 alloy are built, and 300 pounds is

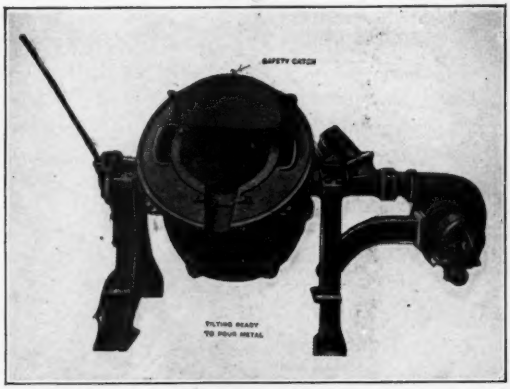

FIG. 7—HAUSFELD-TYPE TILTING IRON POT FURNACE

a common size. In contradistinction to stationary iron-pot furnaces, the tilting iron pots are generally run on strictly intermittent heats. No molten heel is used, and the inside of the pot is scraped thoroughly after each heat. It is easier to clean a tilting pot than a stationary one. On the other hand, the practice of employing a molten heel is also in force at some plants using the tilting furnace.

The pots used in tilting furnaces are always circular in shape, no rectangular pots having been employed in this type. The products of combustion do not have much opportunity to come into contact with the alloy during melting since the pot is heated over its exterior surface by combustion of the

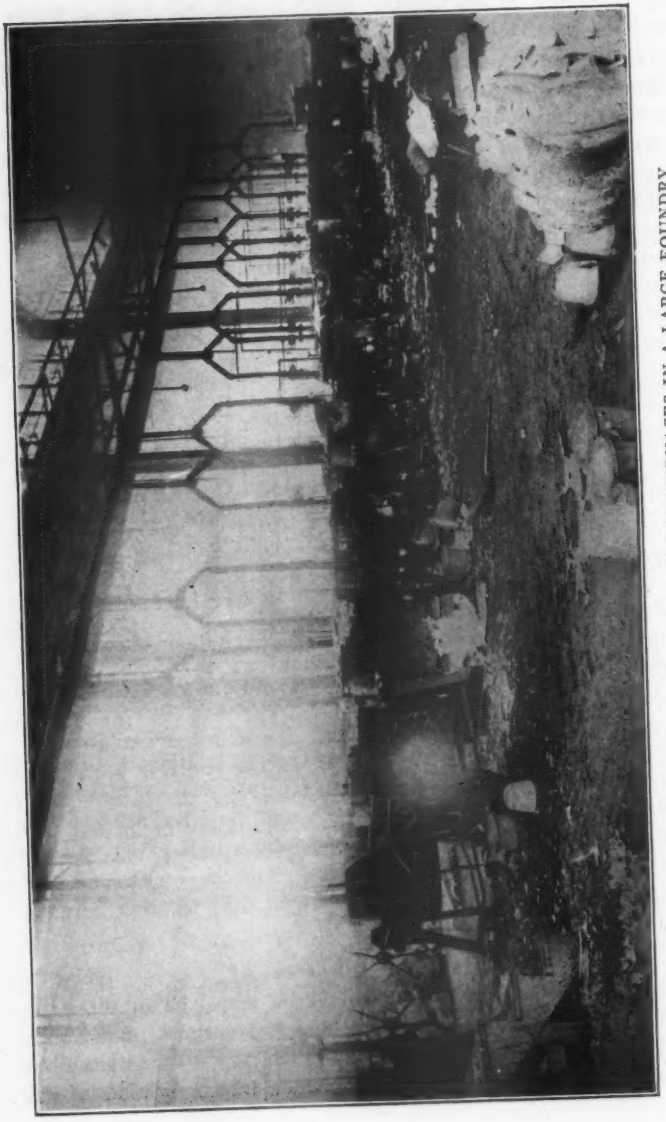

FIG. 8—INSTALLATION OF TILTING IRON POT FURNACES IN A LARGE FOUNDRY

fuel. Where the waste furnace gases are discharged through openings at the top of the furnace adjoining the upper rim of the pot, there is opportunity for the gases to come into contact with the metal. However, in both stationary and tilting iron-pot furnaces, the metal may be regarded, for all practical purposes, as effectively protected from the products of combustion, in contradistinction to the open-flame furnaces where the incandescent combustible gases are directly in contact with the metal during the melting period. The tilting furnace presents some definite advantages over the stationary type, since in the case of the latter the liquid alloy must be ladled out into pouring vessels with resultant additional oxidation and also with much spattering and spilling. Under foundry conditions, the amount of furnace scrap (spills and pouring skims) is usually less than when the stationary furnace is used. Fig. 7 shows the Hausfeld tilting iron-pot furnace, and Fig. 8 shows a view of an installation of tilting iron-pot furnaces in a large foundry.

In general, the performance of tilting iron-pot furnaces is similar to that of the stationary type, as to operating details, and further data need not be included here.

Open-Flame Furnaces

Open-flame furnaces of various designs are favored by some foundrymen for melting light aluminum alloys, principally because of the rapidity of melting that is obtainable. These furnaces, also called direct-flame furnaces, consist of a sheet steel shell, either pear-shaped or cylindrical, lined with a refractory material, and mounted on trunnions. The principal types include the following; pear-shaped (upright) tilting furnaces; cylindrical stationary furnaces; cylindrical tilting furnaces; and cylindrical rotating and tilting furnaces. Open-flame furnaces are fired by oil or gas, and the combustion of the fuel takes place in the space directly above the surface of the metal bath; the alloy is in intimate contact with the products of combustion during melting. In the case of the small single-unit pear-shaped (upright) furnace, two burners are placed in the side at a point midway between the charging door and

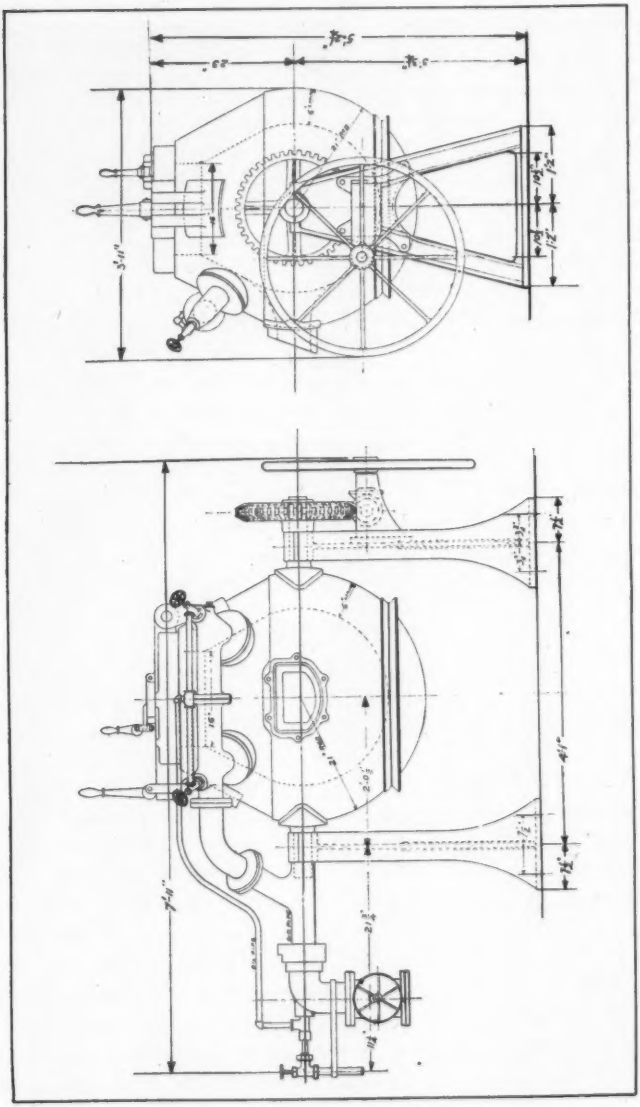

FIG. 9—FRONT AND SIDE VIEWS OF THE 42-INCH HAWLEY-SCHWARTZ TYPE OPEN FLAME TILTING FURNACE

the pouring spout. The furnace is charged through the door at the top, and the metal is poured by tilting the furnace to the proper position. The pear-shaped shell is mounted on trunnions. This type of open-flame furnace may be lined with fire brick or with a rammed lining of gannister and fire clay. Usually, rather small furnaces are employed for melting aluminum alloys, a furnace 42 inches in diameter being a common size, although furnaces up to 75 inches in diameter are used. The operating capacity of the former may be taken as about 300 pounds of No. 12 alloy.

Another form of open-flame tilting furnace is the double chamber type. This consists of two egg-shaped shells, lying with their long axes horizontally, mounted on trunnions, with a connecting space between the two chambers. The charging doors are placed at the top of each shell, and the shells may be tilted individually. Another design of open-flame furnace is the cylindrical or barrel-shaped furnace. A burner may be placed at one end or one burner may be placed on either side of the furnace near the top. These furnaces are usually of large capacity, and they are built to hold up to 3,000 pounds of No. 12 alloy. One design is said to be capable of melting 3,000 pounds of aluminum alloys per hour, or at the rate of 100 pounds in two minutes. These furnaces may be built with two charging doors at one side and one at one end; the pouring spout is placed at the other end. Another type of furnace is the barrel-shaped tilting furnace; the construction is similar to that of the pear-shaped furnace, but it is simply different in shape. A charging door is built in the top, and a pouring spout is placed in one side. One burner may enter through one trunnion, or one or two burners may be placed through the walls near the top.

A barrel-shaped rotating and tilting furnace has been brought out recently. This furnace is made to rotate but it is tilted at right angles to the direction of rotation for pouring. One burner is placed so as to project flame through a hole at one end; the products of combustion are discharged through the pouring spout at the other end. Some other types

of open-flame furnaces are on the market, but their use for melting light aluminum alloys is not known. With particular reference to the open-flame furnaces mentioned above, the pear-shaped (upright) tilting furnace is the most extensively employed of this type for melting light aluminum alloys. The large stationary cylindrical furnace and the rotating and tilting furnace are coming into use now in both foundry practice

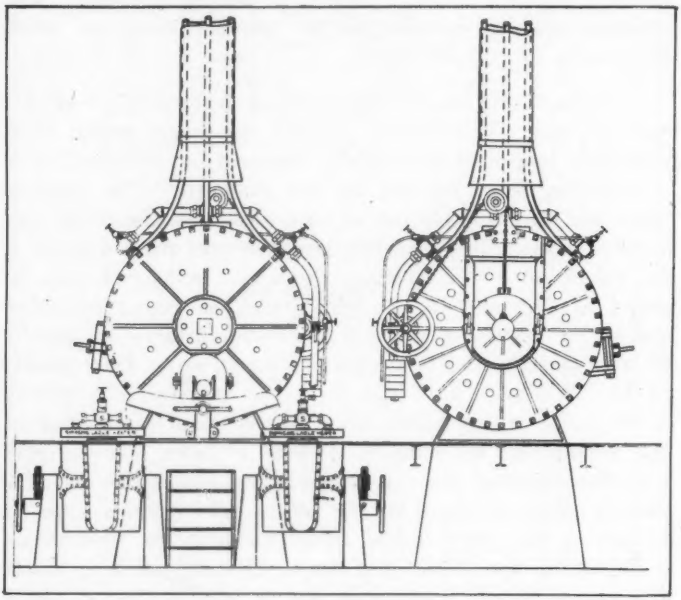

FIG. 10—END VIEWS OF THE SCHWARTZ CYLINDRICAL STATIONARY OPEN FLAME FURNACE

and elsewhere. Fig. 9 is a diagram showing the 42-inch Hawley-Schwartz furnace, in front and side views. Fig. 10 is a diagram showing the large Schwartz cylindrical stationary open-flame furnace of 3,000 pounds capacity. Fig. 11 is a view of the open-flame rotating and tilting furnace, U. S. smelting type.

Most of the data to be given below is for pear-shaped (up-

right) open-furnace tilting furnaces, and the remarks made should not be applied indiscriminately to all types of open-flame furnaces. Open-flame furnaces are very variable as to capacity, but, as indicated above, the pear-shaped (upright) furnace having a diameter of 42 inches and taking from 200 to 300 pounds of No. 12 alloy appears to be the most favored. These furnaces may be lined with a 4-inch thick lining of fire brick, although carborundum fire sand is used considerably. In one installation, a rammed lining of gannister and fireclay, 3 inches thick, is employed. Natural gas and oil are used for the fuel, the latter being preferred. On this installation, the pressure of the air at the burner is from 16 to 18 ounces, and the pressure of the oil is 40 pounds, using a burner supplied with the furnace. In practice, one or two furnaces are handled per furnace tender, and from 200 to 600 pounds of No. 12 alloy are melted per hour. The fuel consumption in these furnaces is variable; in one furnace it was 450 cubic feet of natural gas per 100 pounds melted, while in another, it was 2 gallons of oil. These figures are equivalent to efficiencies of 12.7 and 17.5 per cent respectively. In general, the fuel efficiency in open-flame furnaces of most types appears to be substantially higher than in the furnaces heretofore discussed. Melting costs, for the two furnaces just mentioned, are $0.18 and $0.16 per 100 pounds of alloy.

Open-flame furnaces are the most rapid fuel-fired melting furnaces. Thus, in one plant, with an oil-fired furnace of the pear-shaped (upright) tilting type, six 300 pound heats are obtained in nine hours, with an average melting period of 30 minutes. This is equivalent to a melting time of 10 minutes per 100 pounds of alloy. The life of linings in these furnaces varies, of course, depending on a number of factors. In one plant, a 4-inch thick fire brick lining had a life of about three months, giving 600 heats, melting 200 pounds of No. 12 alloy per hour, nine heats per day. This is equivalent to about 125,000 pounds of metal melted. In another plant, a 300-pound furnace with a 3-inch thick lining of rammed gannister and fire clay gave six heats per day and lasted for four

years. This is equivalent to 7,200 heats and a melting output of about 2,100,000 pounds of metal. The average gross melting loss in open-flame furnaces is generally high, although this is governed principally by the furnace atmosphere and the temperature. As reported, this ranged from 4 to 8 per cent in practice, with an indicated average of 6.7 per cent. This is equivalent to a net melting loss of 4 per cent. Open-flame furnaces are very rapid melting furnaces, and their efficiency as to fuel consumption is relatively high. They give rise to

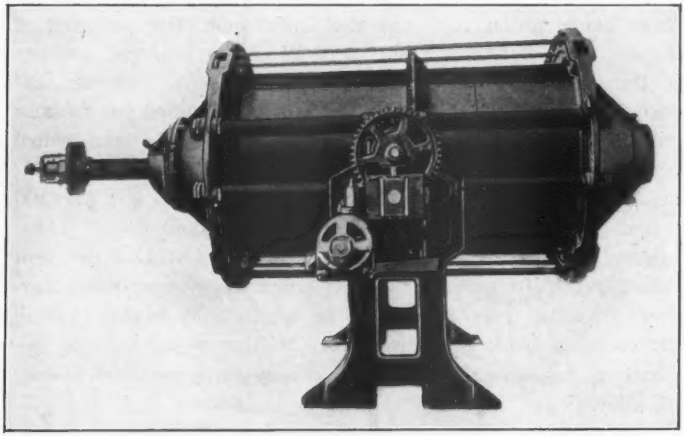

FIG. 11—OPEN FLAME ROTATING AND TILTING FURNACE, U. S. SMELTING TYPE

heavy oxidation losses unless the furnace atmosphere is lean in oxygen, and it may be that such control of the atmosphere will result in heavy fuel losses.

Reverberatory Furnaces

Reverberatory furnaces are used to some extent for melting light aluminum alloys in foundry practice but chiefly for melting aluminum for casting into rolling ingots. Their capacity is small as compared to reverberatory furnaces used in brass and copper practice, and they are generally built to hold 500 to 6,000 pounds of aluminum. There are two gen-

eral types of reverberatory furnaces: (1) those in which the liquid metal is ladled out through a door, and (2) those in which a tap hole and runner are used for tapping. Furnaces of large capacity are required in aluminum rolling mill practice, and it is largely for this reason that reverberatory furnaces have been preferred for ingot casting. In foundry practice, the reverberatory furnace is applicable where the output is large and continuous, but it is necessary that the production of castings be so planned that large heats of metal are not held in the furnace for long periods of time. The "soaking" of aluminum heats in rolling mill practice does not appear to be so deleterious to the quality of the metal as it is to aluminum alloys in foundry practice. The reverberatory furnace is of value also in foundry practice because it permits the charging of large scrap, such as defective crankcases and the like, without breaking. In smaller furnaces, such as the iron-pot furnaces and stationary crucible furnaces of the usual sizes, it is generally necessary to break up all large scrap to admit of charging it. Reverberatory furnaces are used also for running down borings and other scraps in the production of secondary aluminum and aluminum-alloy pig.

The usual type of reverberatory furnace employed for melting aluminum and aluminum alloys consists of a fire brick shell bound together with steel girders (channels and I-beams). The hearth is hollow and usually is built of fire brick while the roof is arched over from one side to the other and generally arched down from front to back in order to deflect the flame and hot gases from combustion down upon the metal. Reverberatory furnaces are fired with coal, oil, or gas. When coal is used, the fuel is burned upon a grate placed in a fire box at the front of the furnace; natural draft is generally used. When fired by oil or gas, the burners are placed usually in the sides of the furnace. The products of combustion are led to a stack via a flue at the rear. In the case of furnaces fired by oil or gas, two to four burners are used.

Reliable data as to the performance of reverberatory furnaces on aluminum alloys are scarce, but in general the remarks

made as to pear-shaped open-flame tilting furnaces above will apply here.

Electric Furnaces

A great many types of electric furnaces are on the market at the present time, and a number of these have been especially designed for the melting of nonferrous metals and alloys, particularly brass. No furnace has been designed especially for melting aluminum and its light alloys, although a number of the standard electric furnaces have been used either experimentally or commercially for this purpose. The idea has been held by some that a superior quality of metal would result from electric furnace melting, but the electric furnace is to be regarded rather as a melting medium for metal rather than an appliance to convert poor melting stock into material of better grade. It may be stated here parenthetically that the electric furnace has been advocated by some on the ground that melting in a "reducing" atmosphere would make it especially applicable for aluminum and aluminum alloys, but there are no actual data which are available in support of this contention. The industrial electric furnaces on the market which have been used either experimentally or commercially are discussed briefly below, and reference may be made to the series of papers by H. W. Gillett in *The Foundry* on the electric melting of alloys for detailed information as to the various types of electric furnaces which are employed for the melting of nonferrous metals in general.

The Baily granular-resistor electric furnace was the type first used commercially, in 1918, for melting aluminum and aluminum alloys, the installation of a 500-kilowatt rectangular furnace at the Massena, N. Y. plant of the Aluminum Co. of America being the first installation, although the tilting type of this furnace had been tried experimentally for aluminum alloys before this time. The large rectangular stationary furnace consists, briefly, of a steel shell with a lining of high grade fire brick backed up by insulating material between the fire brick and the shell. The hearth is bowl-shaped and has a capacity of three to four tons of liquid aluminum. There are doors at both ends of the furnace, together with rabbling doors

on the side opposite the tap hole. This furnace is stationary, and the metal is tapped by pulling out a plug from the tap hole. Running lengthwise of the furnace, there are two resistor troughs made of refractory material and filled with resistor carbon or graphite. The troughs are supported on brick piers. Electric current is sent through the resistor troughs, contact being made through copper terminals at the ends. The heat generated in the trough is radiated largely to the roof of the furnace and then reflected down upon the hearth.

The Baily-type, tilting electric furnace is installed in a few foundries for melting aluminum alloys. The standard 105-kilowatt furnace consists of a cylindrical steel shell mounted on trunnions and arranged with a mechanism so that it may be tilted by hand. A circular refractory trough filled with crushed carbon-resistor material and mounted on a series of refractory piers is the heating element. Current connection is made to the resistor element by means of copper leads terminating in graphite blocks packed against the resistor material. The metal is melted on a hearth below the trough by the heat radiated from the incandescent resistor to the roof and then reflected downwards. The furnace shell is about 7 feet high by 6 feet in diameter, and the capacity is about 500 pounds of No. 12 alloy. The hearth is made of carborundum fire sand, and the roof and sidewalls are lined with corundite brick. A backing of infusorial earth is packed in between the lining and the furnace shell. The current consumption is stated to be about 680 kilowatt-hours per ton of aluminum alloys melted. The furnaces are built in several sizes.

The Detroit-type indirect-arc rocking electric furnace is used commercially for melting light aluminum alloys in foundry practice. This furnace consists essentially of a cylindrical steel shell lined with a layer of corundite brick, which is backed by a course of a less refractory brick chosen for its heat insulating properties, and this in turn is backed by brick of infusorial earth next to the steel shell. The furnace is built in various sizes, but the 1-ton furnace for brass takes about 700 pounds of No. 12 alloy. The furnace proper is mounted on

rollers and ring gears which permit it to be rocked through any arc of revolution up to 200 degrees. The motion is actuated by a small induction motor through reducing gears, and the action of the motor is controlled by an automatic reversing switch which may be set to give the desired angle of rock. The heat is generated by an electric arc from two horizontal graphite electrodes placed axially in the furnace and meeting in the center of the chamber. The electrodes are controlled by hand

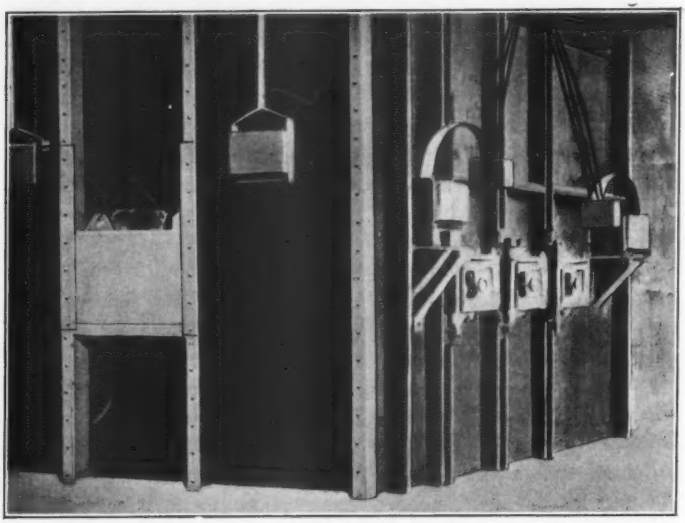

FIG. 12—BAILY-TYPE RECTANGULAR ELECTRIC FURNACE

wheels, and automatic regulation may be applied. During the charging of metal, the electrodes are run back out of the way of the charging door. To operate, the furnace is closed, the electrodes are brought to the pouring position, and the arc is started. The metal is melted by conduction from the refractory lining as well as by direct radiation from the arc. Rocking is started after the metal commences to soften, first through a small angle and finally reaching the maximum angle of rock as the metal enters the stage of superheating. The rate of rock is two complete oscillations per minute. The charging door and

pouring spout are at the center on one side of the furnace, and the furnace may be charged mechanically from above by rotating the furnace so that the door is on top.

The General Electric-type electric furnace is used by the General Electric Co. at several of its plants for melting aluminum and aluminum alloys. This furnace consists of a shallow hearth in the middle of a rectangular furnace shell. Two heating troughs, placed on each side of the hearth and separating the hearth from the side walls, are the source of heat. The heating troughs are filled with granular coke, and two long cross electrodes are placed in the bottom of the troughs. Two vertical electrodes make contact with the cross electrodes through wearing blocks, and the ends of the vertical electrodes are covered with the granular resistor material. The furnace is inherently two phase, each pair of vertical electrodes being connected to one phase. Heat is developed in the resistor troughs by the passage of the current and by the contact arcs at the bottom of the vertical electrode. The heat developed is radiated to the arched roof and thence reflected to the hearth, and the body of granular material conducts heat to the sides and bottom of the hearth.

A number of other electric furnaces have been used experimentally or commercially for melting aluminum alloys, of which the Rennerfelt indirect-arc type has been employed for the preparation of so-called hardeners. The principle of heating is by reflected heat from an electric arc. The Rennerfelt electric reverberatory furnace has been suggested for aluminum melting. This furnace has two melting hearths, and the heat is generated by a resistor trough which is heated by an electric arc from vertical electrodes. The arc may be smothered in the resistor, as in the General Electric furnace, or open. The vertical ring induction furnace (Ajax-Wyatt) has not been used commercially for aluminum-alloy melting, although it is understood that it is to be tried experimentally for this purpose. The Booth indirect-arc type rotating furnace is similar in general construction and principle to other indirect-arc furnaces, and it may be used for melting aluminum and aluminum alloys.

The direct-arc type electric furnace, of which the Snyder furnace is the only one of many of this type which has been applied to copper alloys, has not been used for the melting of aluminum alloys.

Fig. 12 is a view of a rectangular Baily-type electric furnace of 500-kilowatt capacity as designed for aluminum melting. Fig. 13 shows a 105-kilowatt Baily furnace employed for

FIG. 13—BAILY-TYPE TILTING ELECTRIC FURNACE

melting No. 12 alloy in a foundry. Fig. 14 is a reproduction of a photograph showing an installation of two Detroit-type rocking electric furnaces.

Factors Governing The Selection And Operation Of Furnaces

The principal types of furnaces which are employed for melting aluminum and aluminum alloys have been briefly described, and it is evident from the foregoing that the choice of a furnace, from a consideration of all the existing types, becomes a difficult matter. In any case, a choice should be based upon a consideration of (1) the capacity desired; (2) the

melting loss; (3) the cost of installation; and (4) the cost of melting. These factors at least should be given careful attention, and many others should be considered usually before deciding upon any given type. Detailed data as to the structural features of furnaces have not been included here because information as to this has appeared often, and it can be readily obtained from many sources.

It is frequently stated that aluminum and its light alloys readily absorb large quantities of gases on melting and that, therefore, open-flame furnaces should not be em-

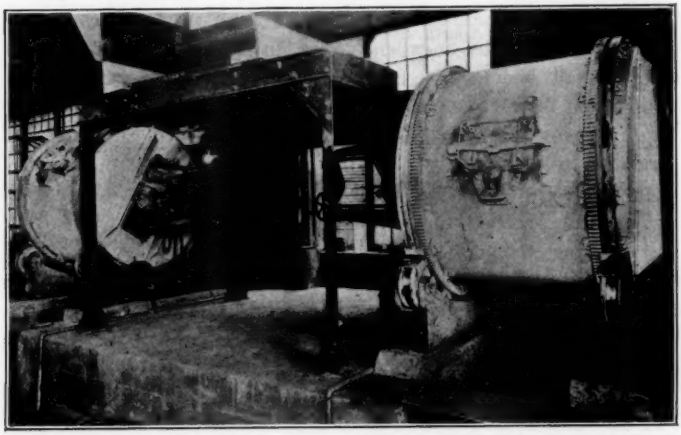

FIG. 14—INSTALLATION OF TWO DETROIT-TYPE ROCKING ELECTRIC FURNACES

ployed. Vague statements of this character are entirely useless, but, at the same time, it is a matter of common knowledge that good practice calls for heating the alloys only to the temperature required for pouring the castings, and this is necessarily variable depending upon the alloy used and the type of castings which are run. Roughly, the pouring temperatures required for No. 12 alloy in foundry practice may be taken as between 650 and 880 degrees Cent. (1202 and 1600 degrees Fahr.), which covers the range for practically all commercial

work, although 750 degrees Cent. is a quite common pouring temperature in heavy automotive work for oil pans and crankcases. On the foregoing basis, the melting temperature need not be more than 50 degrees and never more than 100 degrees Cent., higher than the pouring temperature to allow for any cooling that may take place during the transfer of the metal from the furnace to the molds.

As a general rule, in the industrial operation of furnaces run on aluminum and aluminum alloys, the effort is made to keep the dross and oxidation losses as low as possible. Some foundrymen, however, prefer to have high metal losses for the sake of rapid melting, while others employ furnaces which are assumed to be inexpensive as to fuel consumption with the idea of keeping the melting costs low. In attempting to hold dross losses low, numerous factors involved in metal melting may be overlooked or, at least, disregarded, and the net practical result may be that the melting is exceedingly inefficient from the standpoint of fuel consumption. A cardinal rule in melting practice for aluminum and its light alloys is that the melting temperature should be kept low. The effect of increasing the temperature of melting, at least in an atmosphere containing free oxygen and nitrogen, is to increase the net melting loss.

Acknowledgments

The author is indebted to many foundrymen and metallurgists in the light alloy industry for data and information on the subject under discussion and to some manufacturers of furnaces for the use of illustrations.

Selected Bibliography

Owing to the necessity for presenting only a brief resume' of the original investigation here, it has not been possible to include data published in the literature of aluminum metallurgy, but the following references may be consulted in regard to various aspects of the subject. The bibliography given is a selected one, and the references are arranged chronologically.

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Discussion—Aluminum and Aluminum-Alloy Melting Furnaces

R. J. ANDERSON.—This paper describes the various furnaces employed for melting for foundry purposes and also in rolling.

We were interested in ascertaining what was the loss in the United States involved in melting, both from metal and fuel losses, and we estimated roughly that the total loss is $4,000,000, of which half could be saved if the average practice in melting was increased to the standard of best practice.

Of course we knew from a previous study by Dr. Gillett that the average efficiency of furnaces in the brass industry was five per cent, and we would expect immediately that the average efficiency for aluminum alloy melting could not be five per cent since it requires twice as much fuel to melt aluminum as it does to melt brass. There are a number of figures reported here for melting losses which may seem to some of you excessively high, and I think they are high, but they are actually losses reported to me by operating plants, and I am not responsible for them.

The paper takes up a description of pit furnaces, which are used, as you know, considerably in small foundries, but are exceedingly inadvisable appliances to use for any large production. There are figures given for melting loss on light crucibles, and other items. Then the paper takes up stationary crucible furnaces which are used considerably in American practice.

Tilting crucible furnaces and stationary iron-pot furnaces are used largely. Whether that is the best way to melt or not, nobody knows. At least, we could not find out as a result of all this work.

CHAIRMAN H. B. SWAN.—You have heard Mr. Anderson. I am sure you are all familiar with the vast amount of work which he has done for the aluminum industry and the value of that work, and I know that here this morning there are several men who have had a good deal of experience in melting aluminum. So this topic is one that can be discussed to advantage.

MR. SKILLMAN.—Mr. Anderson nicely side-stepped considerable discussion on his paper by answering such discussion before he let loose. I was going to ask him the best furnace to melt aluminum in. He says that you have to pick your own out, so that is answered. But I think probably there are quite a few men here who would like to know and I think Mr. Anderson ought to be really the one to tell us. Can't you tell us what you consider the best furnace for melting aluminum up to the present time; what is the standing of the electric furnace in this connection, and open-flame furnace, and what are the troubles with the open-pot furnaces at present used? Personally I do not believe we have a good method of melting aluminum at the present time. It seems that the electric furnace has possibilities. It has not come across as many of us have wished but probably future development will help along this line.

R. J. ANDERSON.—Like everyone else, I have intense prejudices on this subject of furnaces, and although I have

no particular reasons for doing certain things, I would not melt with crucibles under any condition for casting alloys. I think in a small foundry where your output is not large, an iron pot furnace is as good as you can do. If your production runs about ten million pounds per annum, I would have a large furnace of the reverberatory or open-flame type. I don't think the capacity should be larger than your molding capacity, but you should supplement that by iron pots to take up the slack. We don't know much about electric furnaces for melting aluminum, the fact of the matter is that no electric furnace has been designed particularly with the object in view of melting aluminum alloys.

One such furnace was designed for remelting aluminum but it is not in operation, generally. Some people who use this furnace find it satisfactory and intend to put in more, but really the electric furnace has not been used sufficiently long to enable anyone to say.

I think the large capacity type furnace—the long barrel-shaped furnace, some twelve feet long and six feet in diameter, is a good furnace provided you control the atmosphere.

R. J. ULRICH.—In regard to aluminum furnaces, I have used an iron pot but I do not find it very satisfactory, so I have substituted a crucible for the iron pot. It beat the iron pot to death in the matter of number of heats. The iron pot in my foundry has lasted a very short time where a crucible will last five or six times as long. From some iron pots I have had four heats, then cutting the furnace down and using the crucible, I can get maybe fifteen or sixteen. Of course on that one iron pot that I only received four heats from, it must have been a defective pot, because out of some of the other pots I received far more. However, they were nothing compared to the crucible. We are putting in the crucible in place of the iron pot.

J. H. VANDERMAN.—We use a tilting pot and our average heats run from eighty-five to ninety, with an iron pot.

How many heats should you get out of an iron pot before it is injurious to the metal?

CHAIRMAN H. B. SWAN.—Our own practice has been to melt in iron pot furnaces of the tilting type. We make our own pots and the average life of the iron pot, which holds about four hundred pounds of metal, is from forty to fifty heats. As to how far you can go without the pot being injurious to the metal, I don't know what I can say. I think that largely depends on the care that you give the pots and the cleaning out. I think the iron pot does have some influence in causing hard spots, although I can not verify that. Perhaps Mr. Anderson can answer that question.

R. J. ANDERSON.—I have figures here to show that the average life of a very large number of pots is forty-seven heats. In another paper which is not quoted here, the question of iron pots is discussed, and of course the life of the pot depends on a number of factors. I don't believe that the chemical composition has very much to do with it, but we really don't know. A cast iron pot should last, say, sixty heats.

J. H. VANDERMAN.—We use a brick so that the flame won't strike the pot. If the flame strikes the pot, it will melt it. Then too, we clean our pots out after every heat.

W. M. WEIL.—I want to say, in this connection, that we have done quite a little work along these lines. We have been able to increase the efficiency of the iron pots that we have used to a point where we are getting today an average of three hundred heats out of a pot. In the first place, we introduce the flame on a tangent. We consider this most important. We also introduce the flame about twelve inches beyond the bottom of the pot—on a tangent tilted at a slight upward angle so that the flame and the heat circle around all the way up. If the flame comes in contact with the pot at all, I am surprised that this gentleman who spoke of four heats even gets that many. If the flame does not touch the pot, and the amount of air and oil properly regulated so that the flame is not too

strongly oxidizing, the pot is not apt to scale and it will last a long time.

There are several other factors, one of which is the shape of the pot. We do not approve of the shape which is most generally used, which is about square. We find it more advantageous to use a pot of small diameter and great depth, thereby reducing the percentage of area which is exposed to oxidation on the top. And the third point is the condition of the inside of the pot. We sand-blast the inside of the pots before using them so as to get them perfectly clean, and then coat them with a solution of lime and silicate of soda. The silicate of soda is merely an agent for applying the lime until heat is applied to completely oxidize it. A pot that is used for a day should be thoroughly cleaned and then lime applied. That will eliminate any possibility of introduction of iron into the aluminum.

I believe that the open-flame furnace is good, but the trouble with a good many is that there is not a sufficiently skilled operator. It must be watched all the time so that you do not have an oxidizing flame. I think, properly controlled, an open-flame furnace is desirable. But our experience indicates that the majority of users of open-flame furnaces have not sufficiently skilled operators to keep reducing the oxidizing flame and the adjustment is so fine on most of the burners that even after the burner is adjusted to produce a reducing atmosphere in the furnace, that a slight change—particles either clogging up or coming out of the orifice of the burner—will change the atmosphere, and it requires an operator to stand there and watch it continuously to be sure that there is a reducing flame.

E. A. ROEDELL.—In regard to the best type of furnace for foundries, I have used quite a few different makes. In my experience I have found only one furnace that did my work satisfactorily. There are a good many foundrymen perhaps who don't like them as well as I do, for as the speaker just said, it takes a skillful man to run

them. I have found that by introducing too much air or too little, we get an oxidizing effect on the metal. Now the way I regulate my furnaces, is that I give them all the heat, when I start them, for about twenty minutes or a half hour at most. After that my flame will extend from the top of the furnace about six to ten inches, and it must be one greenish white flame. Anything over that will show a yellow color or dark red. If it is too much air you will get a long flame out of your furnace. That forces the fire out of the furnace and does not melt.

I have one reverberatory furnace that takes twelve hours for heating before I melt. If my furnace tender is very careful and takes care of his flame, I can get out a ton of nickel within four or six hours. If he neglects that furnace for one-half hour, so that the carbon will clog the flues, and oxidize, it will take about thirty hours to get the metal out of the furnace. This furnace burns from seventeen to twenty gallons of oil per hour depending on the condition of the weather.

Since I have been using oil burning furnaces (I have two of them—an open flame furnace in which I melt copper and my composition, and the other one that I melt aluminum in, which is a crucible tilting furnace) I have had good results with them.

J. H. VANDERMAN.—What pressure do you use?

E. A. ROEDELL.—Eight to ten inches.

MR. SKILLMAN.—Just another word, to say that I guess Mr. Anderson is correct—pick out the furnace you like best.

Iron pots, I think we will all admit, are the simplest, easiest to control, but we can't get iron pots very large. One who has four hundred pounds furnaces has those by increasing the depth of his pots and gaining about one hundred pounds. Now we have a proposition of melting one and a quarter million or one and a half million pounds a month and it takes quite a string of iron pots to get that out unless you work nights. We would like to get

some other kind of furnaces. We use crucibles and iron pots and reverberatories, and we use simplexes, all in daily production. They all have their peculiarities. The iron pots for the small foundry, if you can get along with two or three, are cheapest and best at the present time.

Hard spots from the iron pots can be easily avoided. That question has been taken up in these meetings several times. Coating the iron pot with lime is very beneficial. You can use an iron pot until it is gone without injuring the metal, if you will take proper care. I question the advisability of cleaning after each heat. I think it is better to clean once a day thoroughly and then coat your pots at night rather than cleaning after each heat. I believe you will have more trouble with hard spots if you clean too often.

Iron pots will not last under certain circumstances. Unless you have, like Mr. Swan, your own iron foundry, you have not the ideal condition in getting iron pots. We have had some iron pots that only last one heat, and if we could have used the x-ray on some of them we would never have put them in the furnace. Again, if your furnace is not properly constructed, and you allow your flame to impinge on your iron pot, it will go rapidly. But, if properly constructed, the iron pots at the present time for some capacities are beneficial. For large capacities I still believe that Mr. Anderson is right, that you have to pick whatever is suitable for your own location.

E. F. STONE.—I only want to speak a few words on the iron pot. This gentleman over here has his own iron foundry and probably he knows better what to do than what the non-ferrous men do. A whole lot of the pot failures probably are due to the fact that you do not specify the iron that you need in the pot. When you send the order for a pot to your iron foundry man you do not tell him that you want a heat resisting iron, and consequently he will put in iron of an anlysis for the casting only, and not to resist heat.

MR. SKILLMAN.—If our iron foundry man doesn't know by this time what we use the pots for, he has made enough tons of them to almost know, and when we do specify the iron if we could only get the iron we specify, it wouldn't be so bad.

CHAIRMAN H. B. SWAN.—What is the composition of the pots that you use, Mr. Weil?

W. M. WEIL.—We use a little steel scrap and a little manganese scrap in ordinary gray iron. The last speaker said that we want an iron pot to resist heat. On the contrary, we want an iron pot that will conduct heat. When the pots oxidize they have a tendency to resist the heat and when they get to the point that they are badly burned on the outside, you are well off to throw them away, because they do resist the heat to the extent that they slow the progress of melting to such an extent that we consider them practically useless.

CHAIRMAN H. B. SWAN.—Along those lines, having our own iron foundry we have been able to experiment a little with iron pots, and we have found that in general the causes for failure with a small number of heats is due to faulty molding, such as blow holes or shrinkage in the iron rather than in the composition. On the other hand, if you use an iron pot with a rather high silicon content, the iron is softer and your pot seems to go faster than if you use an iron pot with a low silicon content and low phosphorus.

T. D. STAY.—In our foundries we get from fifty to sixty heats and we whitewash the pots every day, cleaning them only once. I think Mr. Skillman is right about cleaning the pots after every heat. It is liable to cause trouble if your small oxidized particles of iron break off the pot and get into the aluminum and cause hard spots; but the tilting furnace seems to be more generally used than any other and is very satisfactory. However, as Mr. Skillman says, we are looking for a larger unit to take care of every production, and we have not decided, and I don't think

anybody has, as to what the unit will be, whether it will be open-flame or an electric furnace.

Personally I believe that the electric furnace is coming, because you can control the kind of gas that is going over your melt, and that I think is very important.

E. O. ROEDELL.—One word more in regard to large production. In Waterbury the Scovill Manufacturing Co. has four large furnaces in a battery on a second floor. There they melt their large production, preheating the metal. From there to the lower floor they have smaller furnaces—four. For each large one they have one small one, in which to heat the metal, and from there the molder just simply runs over with his ladle and goes to the floor and pours off, which I thought was one of the most proper things to have for large production. I don't know how much those large kettles hold. I have been only once or twice in their aluminum foundry, but it appeared to me that they are handling their aluminum work very satisfactorily. They have, as I said, large kettles above and small ones to heat the metal from which they can take it continuously throughout the day.

The Use of Secondary Aluminum in Foundry Practice

By W. M. Weil, Cleveland

Competition in the aluminum foundry business has caused a marked interest in the use of secondary aluminnm, but its immediate adoption has been attended by disappointments on the part of foundrymen who do not take into consideration the characteristics peculiar to secondary aluminum. This paper deals with some of the causes for these disappointments and suggests some methods for obviating them.

The making of aluminum castings from secondary metal is comparatively simple if the characteristics of the secondary aluminum are considered. The effects of the following elementary conditions of temperature, fluxing and shrinkage are of prime importance.

The temperature to which the aluminum is heated and at which it is poured is important because of the strong affinity of the metal for oxygen. Overheating or burning of the metal produces an excess of dross which is undesirable because of the high melting loss and because it is almost impossible to remove all of the oxide.

Therefore the metal should be poured as close to the melting temperature as possible. The pouring temperature of course will vary according to the thickness and variation in the walls of each particular casting.

Higher Temperature Recommended

Although secondary aluminum is usually a little more sluggish than virgin aluminum, and it must be heated to a slightly higher temperature in order to obtain the same degree of fluidity. This slight increase of temperature, if properly controlled, will not increase oxidation.

Fortunate is the foundryman who knows how to use fluxes properly and applies this knowledge. After the coarse dross which floats on top of the bath of metal has been removed,

there still remains a quantity of finely divided oxide which is not apparent to the eye, the results of which are most harmful. This is the cause of so much of the difficulty encountered by the foundrymen in the use of secondary aluminum, as it is not indicated by the usual chemical analysis.

If not removed the finely divided oxide remains imbedded in the metal, thereby weakening the natural bond between the molecules. This impairs the tensile strength of the metal particularly at the higher temperatures and impairs the ability of the metal to withstand the strains set up in cooling. This results in cracking which is the most common cause in the failure of aluminum castings.

Using Fluxes in Secondary Aluminum

Therefore it is of the greatest importance that this finely divided oxide should be thoroughly removed from the metal. This is best accomplished by the use of a flux consisting of a metallic chloride such as zinc chloride or sodium chloride. Where the addition of zinc is undesirable, the use of copper chloride is recommended but it is seldom used on account of its higher cost. These fluxes are commonly used in foundry practice but frequently fail to accomplish the desired results because they are not properly used. After the dross has been removed the flux should be introduced by immersing it slowly to the bottom of the bath of aluminum and should be held there until ebullition ceases. This can best be accomplished by first placing the flux on the surface of the metal and then immersing it by means of a rod with a spiral coiled loosely at the lower end, which permits the gases to escape upward through the bath. This is most important as otherwise the flux will float on the metal and will act upon the surface only. The flux bubbling up through the bath of molten metal agitates it thoroughly and tends to free the oxide. A layer of this freed oxide will appear on the surface of the bath in the form of a powder and should be completely removed.

The filling of the mold is the next problem. Owing to the low specific gravity of aluminum, the gases which form during the pouring have a tendency to escape through the body of the

metal and as a result the castings are liable to be spongy. In order to prevent this condition, the molds should be made of green sand, lightly but evenly rammed. By the skilful use of vents and the judicious locating of gates and risers, the air can all be readily driven out and a perfectly sound casting can be produced. Cores must be made as soft as possible so that they will crush easily and offer the least resistance to the rapidly shrinking metal. The use of rosin as a binder is advantageous because it softens so quickly from the heat of the molten metal, thereby permitting the cores to crush freely.

Use of Chills Is Undesirable

One of the common practices to which the foundrymen resort to prevent shrinkage cracks is the use of chills. This is not a desirable method of preventing cracks as it cools the metal rapidly in places, thereby producing hard spots. This is particularly undesirable in castings which must be machined.

Knowledge of the tensile strength of secondary aluminum at various temperatures and consideration and allowances therefor are important. It must be remembered that the tensile strength of aluminum is remarkably low at a temperature just below freezing point and that the metal must cool down considerably below the point of solidification before it begins to attain its normal strength. The chief function of the risers is to feed fluid metal into the space left vacant by the shrinking metal in the casting. By attaching the gates to a thin section of the casting and pouring slowly, the shrinkage can be well compensated and the size of the gates and risers can frequently be reduced to an extent that will effect a material saving in the amount of metal to be re-melted.

Experienced foundrymen are able to apply knowledge of these facts so skilfully that they can use a larger percentage of secondary aluminum in the manufacture of castings and produce castings of the highest quality. The failure of aluminum castings often can be attributed to the impinging of the metal against a projection in the mold thereby causing eddy currents and frothing of the metal which results in porosity and blow holes. This is particularly true of secondary aluminum as it

froths readily. Eddy currents can usually be prevented or eliminated by changing the location of the gates and regulating the speed of pouring.

When foundrymen have taken measures for the proper control of the temperature of the secondary aluminum, when they have standardized on a fluxing procedure, and when they have adopted the necessary precautions with regard to shrinkage, they will produce castings of secondary aluminum having a good close grain and superior machining qualities.

It is generally conceded that remelted aluminum is much more uniformly alloyed than the first melting of virgin metals. Uniform hardness and strength results from this more complex mixture, and segregation is practically eliminated in secondary aluminum.

The characteristic drag which is so noticeable in the machining of virgin aluminum castings is entirely eliminated with the result that greater speed of machining can be obtained and a smoother finish produced. These advantages when coupled with the saving in the cost of metal more than make it worth while for foundrymen to take those measures which will enable them to use more and more secondary aluminum in their foundries.

Discussion

CHAIRMAN R. J. ANDERSON.—The subject which Mr. Weil has discussed is of great interest to the makers of alloy castings, and it is a subject which is avoided by makers of secondary ingot. Some foundrymen will not buy secondary ingot and others run their plants entirely on it.

E. J. DECKER.—As I understand it, the chloride is forced to the bottom of the crucible or pot.

W. M. WEIL.—The flux has a tendency to float on top of the metal; but if you take a rod and coil it into a spiral coil and bend it at right angles to the rod, it will form a surface by which the flux can be pushed to the bottom. That will allow the gases to come up between the rod. Great care must be ex-

ercised in immersing flux slowly. Otherwise it will cause a severe boiling which is liable to smash the metal. It is desirable to get the flux to the bottom. In that way the flux will act on the entire body instead of the surface, and the action of the flux together with the boiling will free the oxide which is allowed otherwise to remain in the metal itself, thereby giving a metal which will flow much more freely and which has greater strength because the molecules of the metal will have a chance to form a stronger body.

W. R. DORSEY.—Did I understand that you put the gates on the light part of a casting that had a heavy proportional part, and do not use a chill in order to hold the shrinkage?

W. M. WEIL.—I didn't mean that chill should not be used altogether, but it has been very common practice in the past, particularly some years ago, to use chills whenever a casting cracked. That was the first and about the only remedy used. And the successful foundryman today has found that a great many of his cracks can be eliminated by changing the location of the gates and risers, and their size, thereby eliminating the use of so many chills, which is desirable in castings which have been machined. The cracks cannot be entirely eliminated, but frequently they can be reduced by the more scientific method of properly locating the chill. There are no fixed rules or instructions. It is merely a matter of practice and experience.

E. A. ROEDELL.—Now, in regard to introducing zinc chloride, I would say this: The last thirty years that I have had experience with aluminum, bronze and nickel, I have always made it a point to find a better way of introducing zinc chloride into aluminum. Mr. Weil says that he takes a rod at a certain angle and introduces it in that manner. The very minute your zinc chloride touches the top of your metal, it explodes.

Now here is my way of doing it: Years ago, before we had the phosphorus copper, we had a way of introducing phosphorus. We simply took an inch and a half pipe or inch pipe, took a little fire clay and put on the bottom, blocked up the bottom of our pipe. We dried that over the furnace. The next thing we did was to take our phosphorus, wrap it up in paper, put it in there, using an iron rod somewhat shorter than

the pipe itself. As it was dangerous to put it in, we then stood one side from the pipe, gave it a quick jerk and out came the clay and the phosphorus was on the bottom. The iron rod kept it under the metal and it exploded and the phosphorus was on the bottom. We do the same thing today with our zinc chloride.

I have a number of things to say in regard to molding aluminum. In years gone by we used to take more care of it. We prepared our sand a little bit better. We went to work, used powdered rosin and powdered charcoal—fifty-fifty—and when we got through, we dusted the mold very carefully and blew it out very carefully. As your metal enters on the green sand it is liable to chill off. With this facing of pitch and charcoal we got a nice, smooth surface. As the metal struck it, it started to move and gave more fluidity to the metal as well as a cleaner surface.

W. P. PUTNAM.—I would like to ask the speaker how completely he can remove the oxide from secondary metal by the use of zinc chloride and how does he determine the percentage of aluminum oxide in the metal?

W. M. WEIL.—The method of determining the percentage of aluminum oxide is a very difficult one and much disputed. Some of the very eminent chemists can't agree on the subject. Some of them use one method and some use another. I believe that there is much room for improvement in the method of determining the amount of oxide of aluminum. With the method we have used we have found we can remove all but about two and one-half per cent of the oxide. We have never been able to remove all of it, although we have tried applying this procedure several times. We have also found that it will help the process along by putting a small amount of zinc chloride and some floride, such as calcium floride, in the bottom of the pouring ladle and pouring metal on top of that. That also is helpful. In other words, the process can be repeated a number of times with beneficial effect.

E. H. DIX.—I would like to take issue with Mr. Weil on the question of chills. It has always been my idea that shrinkage must be filled up by risers but that cracks in all castings are due to uneven cooling and that the function of the chill is

to make the heavy section cool at the same rate as the thin section. I think in a large majority of complicated castings it is absolutely necessary to chill the heavy sections so as to promote this uniform rate of cooling, and the function of the chill is to give you somewhere near the same rate of cooling in the heavy section. Therefore, it should not result in particularly a hard structure which would give trouble in machining.

W. M. WEIL.—The use of chills does give a hard structure. That is a well known fact, I believe, that it increases the skin toughness, and increases the tensile strength of the metal. As I said before, the use of chills cannot be entirely eliminated. The cracks are due to shrinkage and the shrinkage can be compensated by the location of the gates and risers in such a position that they will feed hot metal to those thick portions, but in complicated castings it is often impossible to feed the metal into all of those parts. So chills are necessary. But a great many of them can be eliminated.

A. B. CARPENTER.—I would like to ask the speaker if the presence of the powder on the surface of metal would indicate that sufficient flux had been used?

W. M. WEIL.—That is not an indication of sufficient flux, because more oxide on second application would bring it more to the surface. It just appears in that form—a finely divided powder which is red in color.

A. B. CARPENTER.—You add flux until there is no more powder?

W. M. WEIL.—For all practical purposes usually one application is sufficient.

A. B. CARPENTER.—I have sometimes found that the addition of a portion of flux doesn't bring the powder on the top and then by adding more and continuing the stirring, that it finally comes out.

W. M. WEIL.—That is true probably because so many people do not get the flux to the bottom of the pot, and it acts on a portion of the metal only, and then by applying again it acts on another portion. If the flux is properly introduced so that

it acts on the entire body of the metal, one application should be sufficient for all practical purposes.

ADOLPH BREGMAN.—Have you used this on metal from castings as well as metal recovered from drosses, and what success have you had with it?

W. M. WEIL.—We do not manufacture secondary metal castings but there are some concerns that use secondary metal exclusively. We always recommend that a foundryman not attempt to use too much secondary metal, as there are some castings that cannot be made out of secondary metal, and there are not many that can be made out of it exclusively. But of course there are some instances where seconds should be used.

MR. BREGMAN.—Do you mean aluminum recovered from drosses? Is there any difference in the metal used from castings and metal recovered from drosses?

MR. WEIL.—That depends. Metal recovered from drosses can be made as clear as any other metal, and metal recovered from castings depends on what was put into them in the first place, where it is used direct without going through a refining process.

Discussion on Aluminum Foundry Problems

CHAIRMAN R. J. ANDERSON.—We would like to take up a little time in discussing the needs of the aluminum industry, with the idea of having an aluminum session every year at the joint meeting of the American Foundrymen's Association and the Institute of Metals Division.

A number of us have felt for a long time that the technical situation is rather in a backward state, really very much behind actual practice, and there are a very large number of unsolved problems in the industry which we really know nothing about. Of course, many men in the industry are carrying around with them a great deal of information which is known to everybody but officially by nobody, and I think that if some of those men could be induced to put their data on paper, it would serve a very useful end.

Mr. Swan I believe agrees with me on the need of the aluminum industry for more investigative work along actual foundry lines, and if he cares to, I would be very glad to hear from Mr. Swan on this subject.

H. B. SWAN.—I don't think there is any question in the minds of those of us who have had to deal with the making of aluminum castings (I refer more especially to sand castings) that there is need for information on a great many everyday problems. We, all of us, find out something on them when they come up but we don't always have time to work them out to a finish, and what is more, the average foundryman tries a great many things, finally perhaps stops his trouble, but he doesn't make a record of it, and in the end he really doesn't know what stops his trouble.

All of us learn by the experience of those who have gone before us, added to our own, and I think we could all get up and give a number of instances of these problems.

I might say, to cite an instance, that all of us deal with carloads of aluminum. Some of these cars give very good results and we get fine castings, and the next car will come in, the analysis will be fine, but it will run into a lot of cracks. And it doesn't seem to make much difference what you do, until you get rid of that car of ingot you still have trouble with cracked castings. I have talked with a number of men who are considered authorities on this kind of work, and none of them have been able to tell me why that is so. I know that is not peculiar to my own foundry.

Speaking of secondary metal, Mr. Weil's paper brought to mind a case with which I recently came in contact. We had been using virgin metals on particular castings and couldn't see why a remelt wouldn't do exactly as well. In the foundry it gave exceedingly good results, but it wasn't long before we began to have complaints from cars on the road, of fracture of those castings, failure in service; and from examination of the fracture in a crude way outside its course, the section of the casting gave no reason why it should fail. But I believe that perhaps a secondary ingot may deteriorate in the presence of oxide quicker than virgin metal.

There is also the problem of getting longer life out of your pots. These iron pots that weigh four hundred pounds cost considerable money, and where you are melting perhaps fifteen to twenty tons a day, and use a large number of these pots, the bill for your melting runs up considerably. It seems to me that some little research on iron pots would be of value in a monetary way.

I don't know anything else offhand, but there are a number of such problems that come up in everyday life, and if we would make a record of them, and perhaps write our experiences on them, we would find they would be of interest to the other foundrymen and metallurgists when they gather here each year.

I heartily support Mr. Anderson's recommendation along this line.

CHAIRMAN R. J. ANDERSON.—My thought was that it would be profitable, in a joint session to be held annually, to have a symposium. There are plenty other meetings where we can discuss brass, bronze and kindred subjects, but by and large the subject of aluminum has been neglected by the technical societies. There is very largely the fault of the members and technical men engaging in such work.

There are a number of problems which have occurred to me in which I am interested and in which I am sure the industry is interested. Among those is the question of nomenclature for aluminum alloy. Now of course we all refer to aluminum alloys as aluminum, and there is really no more sense in calling such alloys aluminum than in calling brass copper, for example.

I talked with a man recently and I said, "What alloys are you casting here?" He said, "I don't know alloys. I am casting aluminum hardened with copper." Now you find that all around. Men engaged in the business do not realize that they are dealing with alloys, and I think it is wrong to call aluminum alloys, aluminum. There is no systematic nomenclature for this industry. There is a scheme of numbering alloys which is almost as bad, and which I deplore. We all are familiar with No. 12 alloys. Number 12 may mean anything to me—anything under the sun.

I am sure there are other men here who might care to give their views. I will ask Mr. Stay to say a few words if he will.

T. D. STAY.—There are so many aluminum alloys that it seems almost impossible to give them all names. That is the reason why we give them numbers. The No. 12 alloy, or the SAE specification No. 33, certainly has a very definite composition, and I think the tendency nowadays is for the user of aluminum to specify a definite composition rather than an eight per cent copper alloy. They say—SAE specification No. 33, which means 7½ copper, 1¼ iron and 1½ zinc; and it really makes little difference

whether you make that particular composition out of all new metal or out of part secondary and part new metal. If you hold to the composition and keep your temperatures down, you get good castings, but if you let your temperatures get away from you and you let your composition get away from you, you are going to have trouble in your foundry and make your defective losses high.

W. M. WEIL.—The matter of nomenclature and standardization of alloys is important, and I would like to call your attention to the fact that the American Society for Testing Materials, committee B-2, are quite active at the present time, and I believe that they ought to be able to bring in recommendations which everybody can adopt as standard.

As to the procedure of this aluminum meeting or conference each year, I think it is a very good idea, and I think that Mr. Anderson, being quite neutral, probably one of the few neutral men whom we have, will be an excellent man to take charge of this work, and I would like to recommend that he be appointed to proceed with the organization.

CHAIRMAN R. J. ANDERSON.—Of course the small foundryman is in a hard position. I have inquiries from men who are having all sorts of difficulty on questions that I think are fairly settled. But I think a clearing house of this sort would do those men some good, and my particular job happens to be giving service to those fellows who are really in very bad shape.

MR. SKILLMAN.—I don't want to talk too much on this proposition. I have not talked to Mr. Anderson and don't know what his ideas are, but very evidently we could profitably spend at least one session in our yearly meetings on aluminum, and I think we can probably scare up each year enough topics and interesting data to have quite a little discussion. I believe it is pretty much up to foundrymen to support Mr. Anderson and keep him busy. I don't know what his facilities are in Pittsburgh, but it is our own

bureau of mines and we want to look at it that way, and if he has not financial backing we ought to see that he gets it, and use our influence along that line.

I would personally favor having Mr. Anderson, or the bureau of mines, act as a clearing house for information, and more or less present this information for our discussion at these meetings. I believe it would do us all good to loosen up a little bit and say some of the things that we really have hidden under our skins that we don't often let out.

CHAIRMAN R. J. ANDERSON.—I gather from the tone of the meeting that there are no objections to furthering the work of this kind, and I personally will appreciate the co-operation of the men who are in position to give it.

Tests with Cerium in Brass and Steel

By L. W. Spring, Chicago

The data given in this paper is of experimental work done in 1918 and 1919, but no report has been made of it except informally to a few who have had a particular interest. Along with the data lately appearing, describing results obtained by some others who have experimented with it, our tests with this comparatively new metal should prove interesting, even if the report is somewhat belated.

The cerium alloy used was "misch" metal (mixed metal), said by executives of the Fansteel Products Co. from whom it was obtained, to contain around 60 per cent cerium and 25 per cent lanthanum, the remainder being almost entirely other metals of the cerium group. In one brass test a 10 per cent cerium copper alloy was used. The references to cerium throughout this data, therefore, include also the lanthanum and other cerium group metals which the mixed metal carried.

Experiments were made with it in the brass shop, in the cast iron foundry and in cast steel which at that time was being made by the side-blown-converter process. The converter now has been superseded by the basic electric furnace.

Cerium in Red Brass

Three tests of cerium in red brass were made. In each test both 1-inch brass valve body castings and test bars were made from a single pot of about 250 pounds of brass, part of which was poured into the molds without addition of cerium, and part of which was treated with the cerium deoxidizer. The valve castings were carefully inspected and tested for tightness under the usual 150-pound hydraulic pressure. The analyses and the physical tests obtained from the test bars poured at the time are also given.

First Test

(1) One third of a 250-pound pot of red brass was poured off

into a clean, hot graphite crucible and from this into molds, test bars and 1-inch gate valve bodies.

(2) To the remaining two-thirds, two ounces of mixed metal were added by means of a phosphorizer, the metal stirred and one-half of it poured into test bars and valve bodies. Calculated cerium was .075 per cent. Metal was as hot or hotter than in (1).

(3) To the remaining third of the pot another ounce of cerium was added and similar molds poured as in (1) and (2). Calculated cerium was .15 per cent. The metal was a little cold.

There was a blue flame and some smoke when the two ounces of cerium were added but no violent reaction. The castings were normal in color. The fracture of those with cerium showed segregation and a gray rim. The fracture of those without cerium was normal.

Amount mixed metal added	Per cent cerium	Sn.	Pb.	Cu.	Fe.	Zn.
1 None	0.000	6.13	2.36	81.55	0.27	9.59
2 2 oz. to 166 lbs.....	0.075	6.15	2.85	82.52	0.20	8.49
3 1 oz. to 83 lbs.....	0.150	6.27	2.66	82.00	0.20	8.50

	Valve bodies poured	Leakers per cent above normal	Tensile strength	Yield point	Per cent elongation in 2 inches	Fracture
1.....	30	Normal	38,300	20,800	20.0	O.K.
2.....	24	58	32,100	20,700	12.5	Seg. gray rim
3.....	24	63	29,800	22,100	9.5	Seg. gray rim

Second Test

One ounce of cerium was thrown into the red hot crucible as one-third of a 250-pound pot of red brass was being poured into it. This metal was then poured into 1-inch valve bodies, test bars, etc. The remaining two-thirds, which, of course, contained no cerium, was poured into similar molds, those from the last five molds poured being taken for comparison with those poured from cerium treated metal.

	Amount mixed metal added	Per cent cerium	Sn.	Pb.	Cu.	Fe.	Zn.
1.	None	0.000	5.07	1.65	84.26	0.27	8.33
2	1 oz. to 83 lbs.....	0.075	5.26	1.92	84.28	0.25	8.24

	Valve bodies poured	Leakers per cent above normal	Tensile strength	Yield point	Per cent elongation in 2 inches	Fracture
1.....	29	Normal	35,600	21,400	20.5	O.K.
2.....	24	51.3	33,050	20,875	15.5	Seg. gray rim

Third Test

Half a pot of red brass was poured into another heated crucible and then into molds. To the remaining half, 23 ounces of 10 per cent cerium copper alloy were added, the metal stirred well and poured. There was no difference in the appearance of the molten brass with and without cerium copper.

Am'nt alloy added	Per cent cerium added	Valve bodies poured	Leakers Per cent above normal	Fe.	Tensile strength	Yield point	Per cent elongation in 2 inches	Fracture
none	0.00	63	Normal	0.06	35000	21400	18.0	O.K.
					33400	21500	14.0	O.K.
23 oz. 10 per cent Ce Cu to 125 lbs.	0.115	63	72.8	0.06	30400	19950	14.0	Flaw Seg.
					28450	19820	10.5	Flaw Seg.

The fractures of the valve bodies without cerium were uniform and normal. The fractures of the valve bodies treated with cerium were segregated with gray rims. The leaky bodies with cerium, when broken through the leaky spots, showed very spongy metal and some inclusions.

Summary

These tests show that the precentage of castings which leak rises with addition of cerium and the tensile strength and ductility of the metal decreases. Therefore, as a deoxidizer for leaded brasses, cerium has no value, as it causes segregation and spongy, leaky castings. Tests were not made on brasses and bronzes without lead, as for these, or at least for the copper-zinc alloys such as the manganese bronzes, aluminum is an effi-

cient and much less costly deoxidizer. It is well known that aluminum cannot be used in alloys that contain lead and it appears and seemingly has been proved by these tests that cerium has a similar action with lead. It is stated by others who have tried cerium in brass that the inclusions noted in leaded brasses are cerium lead alloys.

Tests on Cast Iron

Tests were made with cast iron. From the same ladles of soft cast iron from the cupola, test bars and some 2½-inch cast iron tees were poured, part without and part with cerium calculated to give sufficient of the cerium metals to considerably reduce the sulphur and phosphorus content, as the claim had been made that cerium acted upon phosphorus and sulphur in the irons and steels.

In the two tests made with gray iron the cerium was thrown into the shank ladle as the iron was being poured in from the bull ladle. The reaction was not violent. The iron was well stirred before pouring. The metal was fluid but considerable slag came to the top of the ladle. The molds poured with cerium showed much greater shrinkage in the gate, i.e., the iron apparently fed better.

First Test

	Mixed metal addition	Per cent cerium	Per cent Si.	Mn.	Sul.	Phos.	Gr. C.	C.C.
1.	None	0.00	2.44	0.51	0.127	0.81	3.30	0.10
2.	½ lb. to 100 lbs.	0.50	2.44	0.41	0.111	0.79	3.24	0.10

Second Test

3	None	0.00	2.44	0.53	0.115	0.76	3.30	0.10
4.	½ lb. to 100 lbs.	0.50	2.54	0.60	0.104	0.75	3.30	0.10

	Tensile strength	Transverse strength	Deflection	Brinell hardness	Shrinkage	Leakers Per cent above normal
1.	23060	2775	.10	187	.115	Normal
2.	26760	2935	.13	175	.113	Normal
3.	{ 24960 } { 24960 } { 27570 }	2870	.11	150	Not det.	Normal
4.	{ 26300	2980	.12	150	.119	Normal

Results of Tests on Converter Cast Steel

Converter blow	Cerium pounds	Added per cent	Amount found	Si.	Mn.	Sul.	Phos.	C.C.	Tensile strength	Yield point	Per cent Elon. in 2 in.	Per cent Red. of area	Fracture
1565	None ...	0	0	.42	.84	.086	.054	.37	90250	51900	22.0	31.2	Fibrous
	½ to 100	.5	.16*	.42	.82	.043	.056	.41	98050	51250	20.0	24.5	Fibrous
									68500	47500	4.0	17.1	Dirty brown and gray
1598	None ...	0	0	.32	.75	.088	.056	.40	89000	46500	20.0	25.8	Fibrous
									90400	50500	20.5	23.4	Gran.
	1 to 100.	1	Not det.	.32	.79	.036	.051	.39	91100	46550	21.0	32.0	
									83250	49500	7.0	..	Broke in shoulder—dirty
1643	None ...	0	0	.30	.70	.081	.057	.36	81750	44500	18.0	24.1	Gray Fir-tree
	1 to 100.	1	.44*	.32	.71	.027	.051	.36	77800	35300	26.0	42.1	Fibrous
1826	None ...	0	0	.32	.73	.084	.063	.37	85050	49750	21.0	25.9	Gray Fir-tree
	1 to 100.	1	Not det.	.33	.72	.041	.063	.36	97250	53600	25.0	32.2	Gray Fibrous

*Determinations made by United States Bureau of Mines.

Summary (Continued from Page 629)

Test	Reduction of sulphur Per cent	Increase in tensile strength Lbs.	Per cent	Increase in tran. strength Lbs.	Per cent	Increase in deflection Per cent
First	.026	3700	13.6	160	5.8	.03 = 30
Second	.011 = 10	1975	= 7.9	110	= 3.8	.01 = 9

Converter Cast Steel

Additions of one pound of the cerium alloy were made to 100 pounds of converter cast steel of four heats. With the steel tests a difficulty was that the necessity for particularly hot metal for the small castings necessitated the pouring of small quantities of steel rather quickly after addition of the deoxidizers in order to avoid too great cooling of the metal. No castings were poured for test, regular physical test bars and samples for chemical analyses, only, being taken.

The mixed metal was tossed into the stream of steel as it was being poured into a hand ladle. Test bars with and without cerium were poured from each blow. The reaction of steel and cerium was not violent. The steel with cerium seemed to stay alive and "worked" longer than that without. A white slag formed on top of the steel in the ladle and some came to the tops of the risers after the steel was poured. Excessive shrinkage took place in the risers. The steel was fluid. The results are shown in tabulated form on the opposite page.

The first two converter blows tried, Nos. 1565 and 1598, gave rather erratic results in the physical tests. Blows Nos. 1643 and 1846, however, show that cerium has an important effect upon steel, increasing the elongation and reduction of area and reducing the sulphur without affecting the percentages of any other metalloid.

The results are summarized below.

SUMMARY

Heat No.	1565	1598	1643	1826
Sulphur before addition.....	0.086	0.088	0.081	0.084
Sulphur after addition.....	0.043	0.036	0.027	0.041
Loss of sulphur.....	0.043	0.052	0.054	0.043
Per cent removed.....	48.8	59.1	66.7	51.2

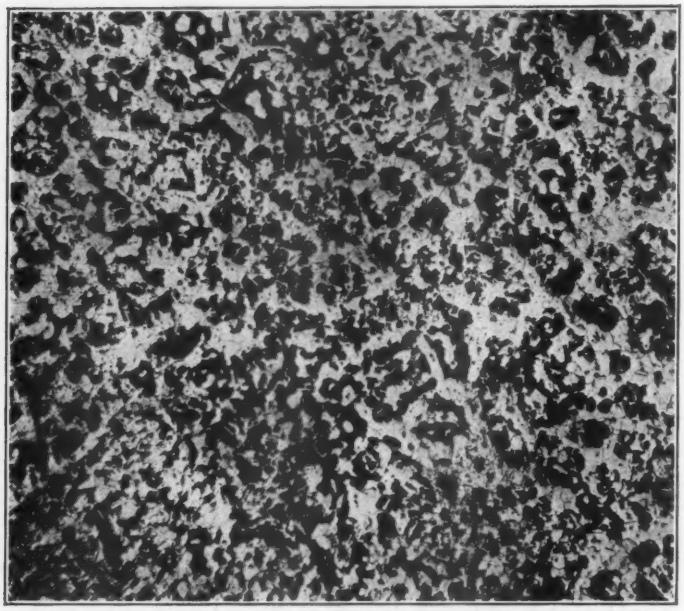

FIG. 1—BLOW NO. 1643 WITHOUT CERIUM X 65

Analysis: Silicon, 0.30; manganese, 0.70; sulphur, 0.081; phosphorus, 0.059; combined carbon, 0.36 per cent. Tensile strength, 81,750; yield point, 44,500; elongation in 2 inches, 18 per cent; reduction of area, 24.1 per cent.

All of the test bars were annealed in the laboratory from six to eight hours at 1700 degrees Fahr. and cooled in the furnace, which was the regular works practice for steel castings. The low results of the last bars tested from blows Nos. 1565 and 1598 were due to the rusty colored inclusion, probably an oxide, from which the metal did not free itself. This was not the case with the other bars, which were clean. During the testing of one or two of the bars a faint odor which we thought was acetylene was given off. Such an odor has also been remarked by H. W. Gillett, of the United States Bureau of Mines, who has recently made some cerium steels.

The test blocks on blow No. 1598, on the under side of which the bars were cast, were sawed in half. The shrink cavity

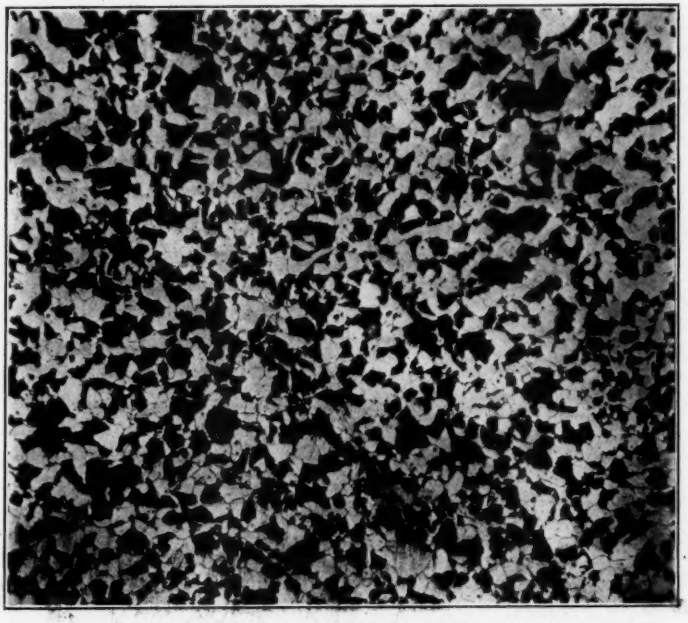

FIG. 2—BLOW NO. 1643 WITH CERIUM X 65

Analysis: Silicon, 0.32; manganese, 0.71; sulphur, 0.027; phosphorus, 0.051; combined carbon, 0.36 per cent. Tensile strength, 77,800; yield point, 35,300; elongation in 2 inches, 26 per cent; reduction of area, 42.1 per cent.

of the cerium steel bar was approximately of the same size as that in the regular steel bar from the same blow not treated with cerium.

A particularly noticeable effect was the appearance under the microscope of the steel treated with cerium. Fig. 1 shows the steel of blow No. 1643 without cerium. This shows what is known as "ingotism," a nonuniform structure caused by the crystallizing of the ferrite (white) areas in "strings" around the small inclusions, consisting of more or less emulsified manganese sulphide, oxides, slag etc., which serve as nuclei. These inclusions do not appear in the steels after treatment with one per cent of cerium, as is shown in Fig. 2, the manganese sulphides,

oxides, etc. having been removed by the cerium so that the steel is really much cleaner. This is an end which is desirable in steelmaking. Steel which is clean and of such uniform structure as that shown in Fig. 2 has much more ductility than steel which carries oxides and emulsified slag. The lowered sulphur accounts for much of this, ingotism once formed being extremely difficult to break down, higher temperatures and more drastic annealing being necessary.

Where and When The Foundry Should Use Electric Heat

By E. F. Collins, Schenectady, N. Y.

To operate a certain process with fuel that might much more advantageously be replaced by electric energy is not economy, yet many such cases exist today. There are many combustion devices operating that should long since have been scrapped for the electrical.

The accompanying chart, Fig. 1 shows the relative costs of three common sources of heat, namely, coal, gas, and fuel oil, and electricity; in terms of dollars per 100,000 B.t.u.'s utilized in baking ovens and furnaces. This chart in itself is evidence of the fact that consideration other than B.t.u. cost determines the true efficiency for thermal processes. Were this not true, how could the electric furnace exist, and how could it show the greater overall economy that it does in many processes today? Neither could the two other fuels listed compete with bituminous coal, except that the application of fuel oil or gas carried with them inherent advantages that completely outweigh the difference in cost of the B.t.u. supply, and this is the true reason for the use of oil and gas as against bituminous coal for many thermal processes.

Electricity Offers Safety, Uniformity and Economy

In the same manner and for the same reason that gas and fuel oil are recognized as standard methods for carrying on certain heating processes today with higher economy than with coal, so is electric heat today recognized by competent engineers as the last word in carrying through many thermal processes with the maximum safety, uniformity and economy.

It is only a matter of time until the use of electric heat for complex thermal processes will be adopted with no more hesitation than now occurs when the householder decides in favor of the electric light for his home as against the gas lamp even though the cost of current consumed be greater than the gas.

The chart in Fig. 1, also illustrates well a valuable characteristic of electric heat. It will be noted that the cost of burning fuels varies widely depending upon the amount of air admitted to furnace and the resultant combustion, for example, the cost of city gas for 100,000 B.t.u.'s effective rises to double its value with an increase of 50 per cent in air, and such excess

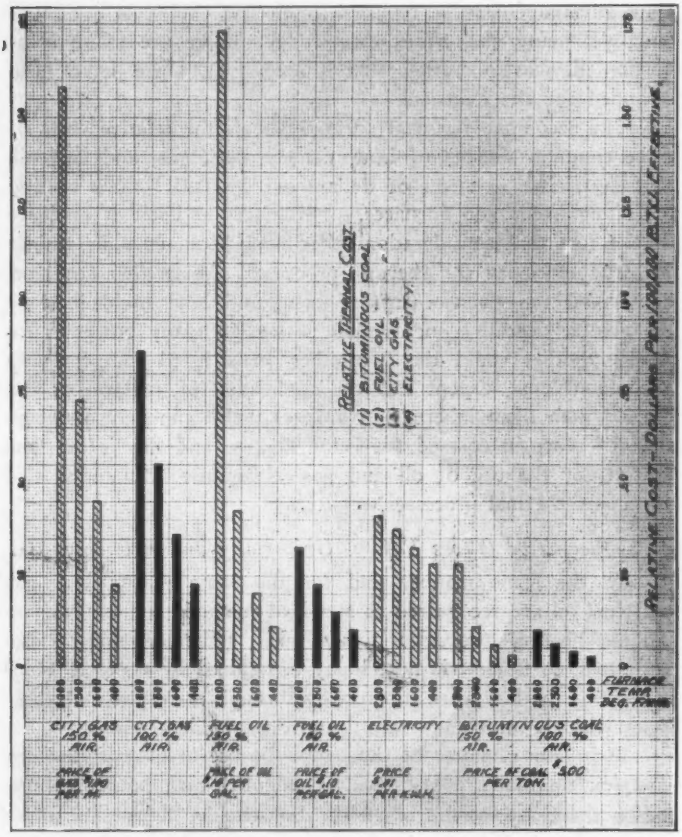
RELATIVE THERMAL COST
(1) BITUMINOUS COAL
(2) FUEL OIL
(3) CITY GAS
(4) ELECTRICITY
RELATIVE COST - DOLLARS PER 100,000 B.T.U. EFFECTIVE
FURNACE TEMP. DEG. FAHR.
CITY GAS 150 % AIR.
CITY GAS 100 % AIR.
FUEL OIL 150 % AIR.
FUEL OIL 100 % AIR.
ELECTRICITY
BITUMINOUS COAL 150 % AIR.
BITUMINOUS COAL 100 % AIR.
PRICE OF GAS $.10 PER M.
PRICE OF OIL $.10 PER GAL.
PRICE OF OIL $.10 PER GAL.
PRICE $.01 PER K.W.H.
PRICE OF COAL $.00 PER TON.

FIG. 1—RELATIVE COSTS OF COAL, GAS, FUEL OIL AND ELECTRICITY IN DOLLARS PER 100,000 B.T.U.'S UTILIZED

percentage of air is by no means rare. Fuel oil likewise increases its cost roughly four times at the same temperature, 2800 degrees Fahr., and the same excess of air of 50 per cent. Hence, it is seen to how great an extent the economic operation of the fuel furnace is in the hands of the operator. This handicap does not exist with the electric furnace where the ratio of conversion from power to heat is 100 per cent perfect and the operator can not affect this efficiency of conversion even if he so desired.

Heat Generation in Electric and Fuel Fired Furnaces

In the electric furnace, heat generation can be kept nicely balanced against heat absorption by the charge. The importance of this fact cannot be over emphasized, since the problem of heat absorption is of first importance in all heating and especially combustion furnaces. It goes without saying that efficient generation or development of heat units by chemical oxidation means little, unless the B.t.u.'s released are in a minimum constant proportion to the B.t.u.'s absorbed in doing useful work. Hence the rate of heat generation and heat absorption must be controlled skillfully to guarantee maximum overall efficiency.

To burn fuel correctly, therefore, is only the first step that has an immediate bearing upon practical results, and this fundamental truth should be recognized by all furnace users. All B.t.u.'s that fail to be absorbed by the charge are simply wasted, no matter how efficient the burners and resultant combustion may be, and in this lies a definite handicap if the rate of generation to absorption is not properly governed.

If the fluid be the product of combustion as in a fuel-fired furnace consisting largely of CO_2, water vapor and nitrogen, then currents and eddies exist in the combustion chamber, due to changes in densities depending in part on variation in temperature. These gases have a continuous flow and practical results are obtained by removing as much heat as possible from such streams while they are passing through the furnace to the stack. This aim is accomplished more or less satisfactorily by

designs which allow the charge to be swept uniformly and enveloped to the maximum by the stream of hot gases.

Hot Gases Shift Erratically

Complete and properly regulated envelopment is necessary to a uniform and high rate of heat absorption, which is dependent upon heat conductivity of the charge and the area of surface contact. If only parts of the body lie in the stream

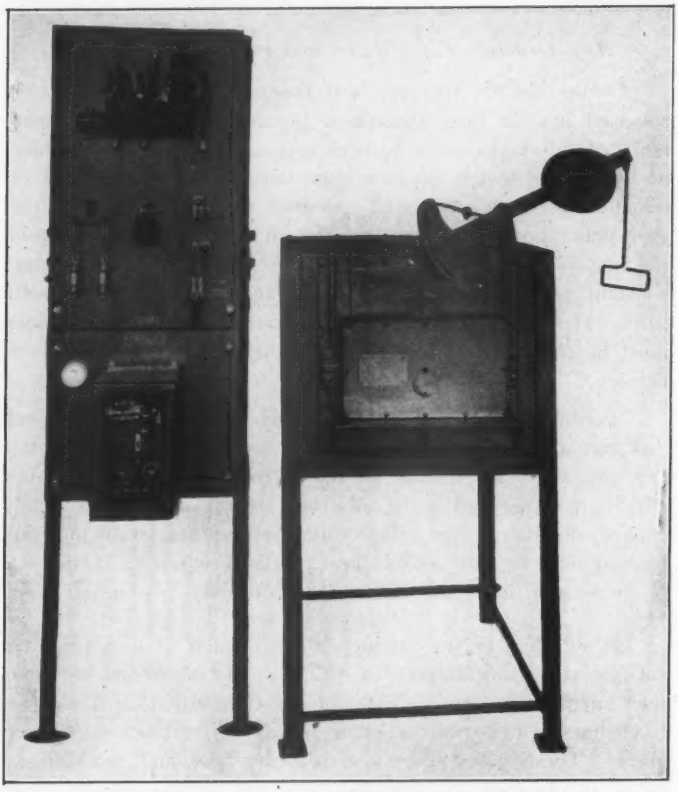

FIG. 2—(RIGHT) ELECTRIC RESISTANCE FURNACE HAVING A HEARTH 10½ X 21 INCHES. (LEFT) CONTROL PANEL FOR AUTOMATIC TEMPERATURE CONTROL

or if the streams vary in velocity or temperature, we may expect nonuniform heating of that body. It should be remembered that in fuel-fired furnaces, especially where forced draft is used, that these currents of hot gases have a cyclonic violence and continuously shift as erratically.

A few illustrations out of the many working installations will be noted in order to indicate the applicability of electric heat to advantage in the foundry. It is not to be inferred that electric heat is without a competitor in all places and under all conditions. There are, however, a great number of applications which may be electric with advantage. These applications in various processes occur with so great frequency that it behooves the user of heat processes to question his furnace engineer thoroughly concerning the possibilities of electric heating before revamping existing installations or adding new thermal process equipment, which employs fuel-fired heating methods.

Advantages of Portable Metallic Resistor Furnace

Fig. 2 shows a portable metallic resistor furnace for temperatures up to 2000 degrees Fahr. This furnace has a hearth dimension of 10½ inches wide by 21 inches long. The control panel for automatic operation is shown at the left. This furnace is ideally suited for annealing, hardening, and tempering or drawing of dies or small tools in the tool room. Likewise it is suited to any heating requirements where the charge does not require more than 1800 degrees Fahr. Some of its advantages over fuel-fired unmuffled furnaces are as follows: 1. Radiant heat; 2. satisfactory heat distribution; 3. automatic control of temperatures if desired; 4. practically nonoxidizing atmosphere if desired; 5. small amount of heat given off to the room; 6. no products of combustion or obnoxious gases given off to heating chamber or room; 7. ratio of heat generation to heat absorption by charge correctly maintained; 8. uniform and complete penetration of heat through charge without overheating of corners, fins or surfaces; 9. ability to repeat desired heat cycles giving uniformity of product; 10. a reduction, generally, in labor; 11. a better overall economy and the production of higher

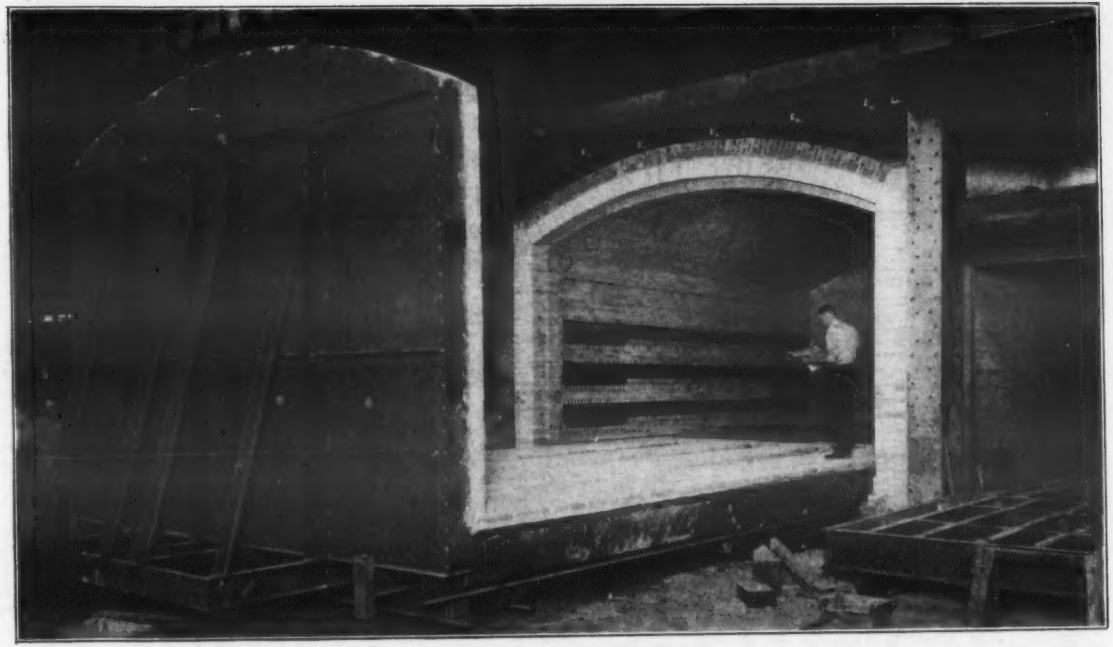

FIG. 3—ELECTRIC HEAT TREATING FURNACE EQUIPPED WITH AUTOMATIC TEMPERATURE CONTROL. HEATING CHAMBER IS 15 FEET 10 INCHES WIDE, 27 FEET 7 INCHES LONG AND 8 FEET 7 INCHES HIGH. THE MAXIMUM OPERATING TEMPERATURE IS 1000 DEGREES FAHR. IT UTILIZES 620 KILOWATTS AT 550 VOLTS, 3 PHASE

quality product at the same or slightly higher cost or the same quality at a lesser overall cost.

A large furnace for normalizing and annealing large foundry castings is shown in Fig. 3. This has been in use for several months and is giving great satisfaction in the foundry of the General Electric Co., at Schenectady.

Electric Furnaces Are Utilized for Core Baking

A four-drawer foundry core-baking oven is shown in Fig. 4. This oven operates at 375 degrees Fahr. and has a 35 kilowatt

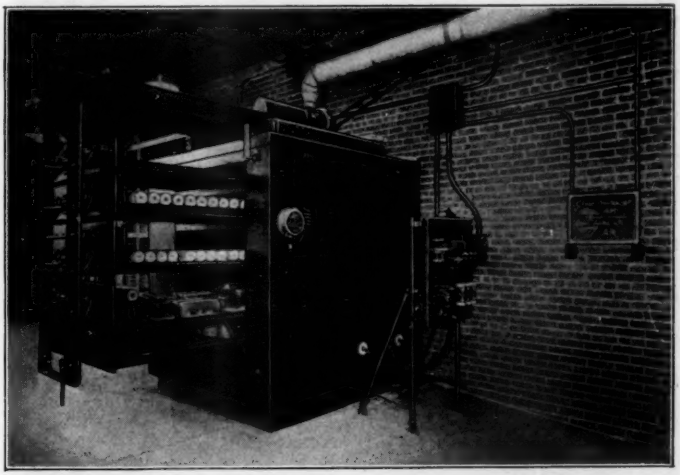

FIG. 4—FOUR-DRAWER CORE BAKING OVEN 6 FEET 4 INCHES LONG, 4 FEET 9 INCHES WIDE AND 6 FEET HIGH. THE CONNECTED LOAD IS 36 KILOWATTS AND THE MAXIMUM OPERATING TEMPERATURE 375 DEGREES FAHR.

connected capacity. Its dimensions are 6 feet 4 inches long, 4 feet 9 inches wide and 6 feet high. Fig. 5 shows one of a battery of ovens in use for making automobile engine cores for a number of high-grade car manufacturers. Core weights vary from 3 to 128 pounds each. A heavy linseed oil binder is used which makes it necessary to provide ventilation and hence heat in excess of the requirement of the ordinary core

compounds. The inside dimensions of the oven are 5 feet wide, 10 feet deep and 7 feet high. The connected load in heaters is 86 kilowatts. Automatic control of temperature is employed. Baking temperature of 425 degrees Fahr. is used and this reduces the baking time from one to three hours over that required by the gas oven operating at 350 degrees Fahr., which was the highest practical baking temperature with gas heating. Four of these ovens work at efficiencies varying from 10.9 to 14.6 pounds of green cores baked per kilowatt-hour of

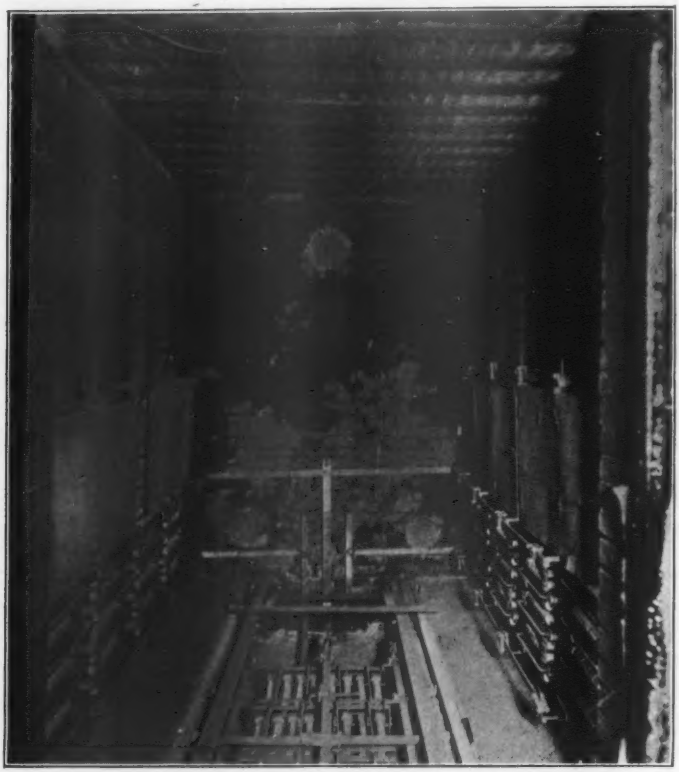

FIG. 5—INTERIOR OF A CORE BAKING OVEN SHOWING THE HEATING ELEMENTS

power consumed. The total cores baked in four ovens in one week was 108,730 pounds with a power consumption of 9389 kilowatt-hours, giving an efficiency of 11.6 pounds of cores per kilowatt-hour. During a year period, these ovens did not turn out a car of burned, cracked or imperfectly baked cores. Reports from more than 15 users of electric core baking ovens acknowledge them to be a most satisfactory solution of the foundry core baking problem.

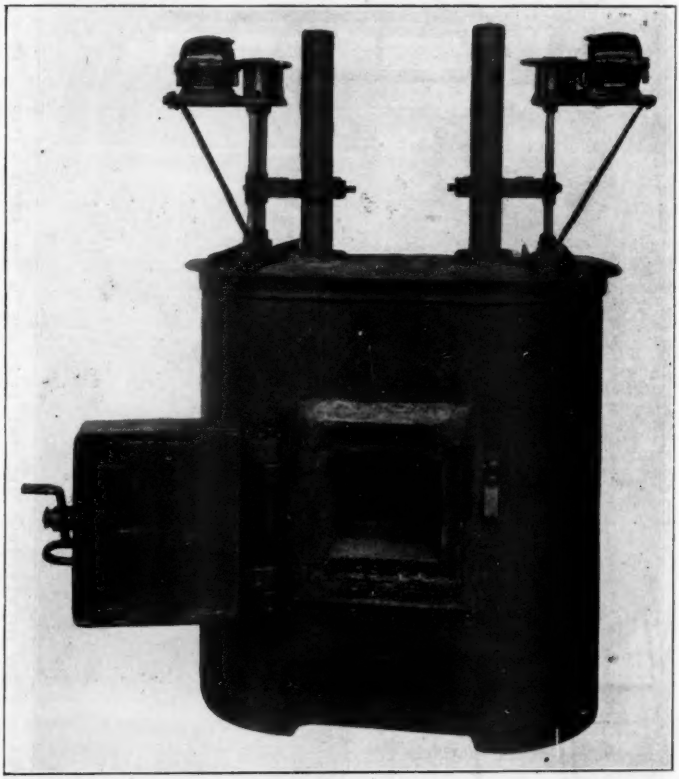

FIG. 6—ELECTRIC MELTING FURNACE WITH A CAPACITY OF 50 POUNDS. IT IS OF THE 40-KILOWATT, SINGLE PHASE, MUFFLED-ARC TYPE

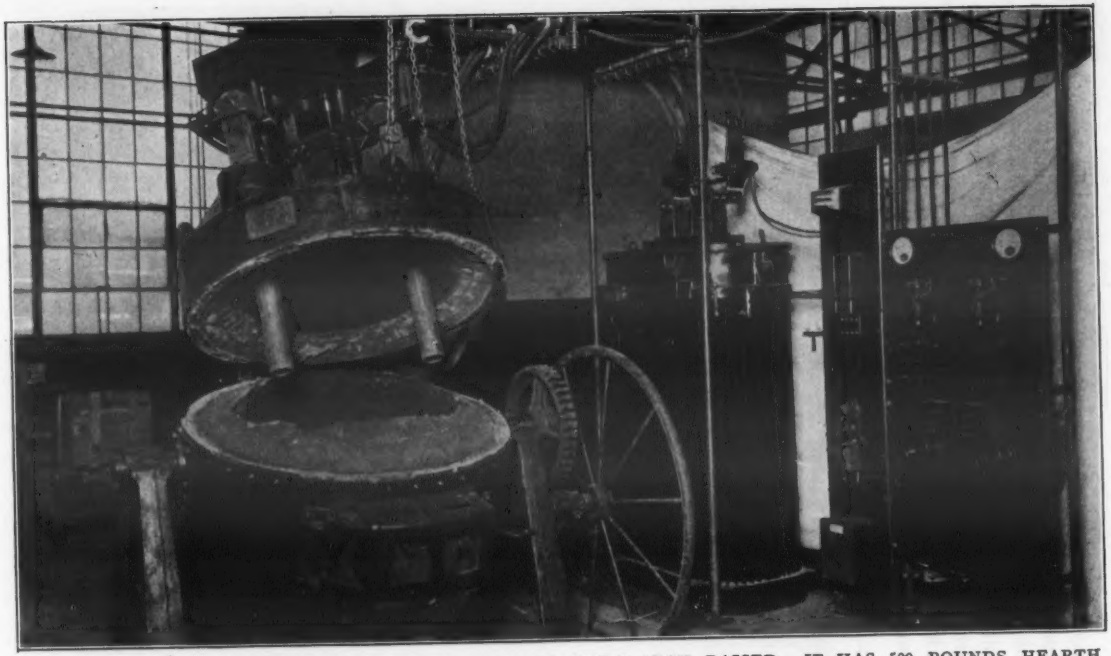

FIG. 7—FRONT VIEW OF ELECTRIC MELTING FURNACE WITH ARCH RAISED. IT HAS 500 POUNDS HEARTH CAPACITY. THE CONNECTED LOAD IS 100 KILOWATTS, 3-PHASE

Fig. 6 shows the muffled arc type of melting furnace. A similar furnace is automatically controlled and suited for all temperatures up to 3000 degrees Fahr. Normally it carries 50 kilovolt-amperes connected capacity and will melt 75 pounds of copper per hour. It will carry a 50-pound crucible on its flat hearth. It is well able to afford facilities for melting small quantities of metals or alloys or serve as general laboratory furnace for high temperatures. Another furnace of the same type is designed in larger units to melt nonferrous metals. The furnace is 3 phase. Each of the two vertical electrodes form contact resistance arcs in a pot of granular graphite, the contents of the two pots being connected by carbon conductors embedded beneath the hearth.

The furnace shown in Fig. 7 has a hearth capacity of 500 pounds of brass, and with 100 kilowatts connected, will melt yellow brass in pig or heavy scrap form at the rate of 500 pounds per hour and with a metal loss of less than 1.5 per cent and a power consumption not in excess of 450 kilowatt-hours per ton. Copper is melted at the rate of 500 pounds per hour with a power consumption of 475 kilowatt-hours per ton. This power consumption is based upon melting not less than 500 pound charges and allowing 20 minutes per heat for charging, pouring and foundry delays. The furnace normally is provided with a hand tilting wheel and two electrode motors, both of which are of alternating current type, so that the necessity for a direct-current motor-generator set, usually required for furnishing direct current to the control motors, is eliminated. The air-cooled electrode clamps and roof outlets are free from water cooling, avoiding the necessity of supplying any cooling water whatever.

Furnaces Adapted to Melting and Annealing Malleable

The foregoing has been reviewed with the standard gray iron and brass foundry in mind. It may be interesting to inquire into the apparent possibilities of accomplishment when electric heat is employed in the malleable iron foundry for melting and annealing.

In order to point out some of the worth while advantages

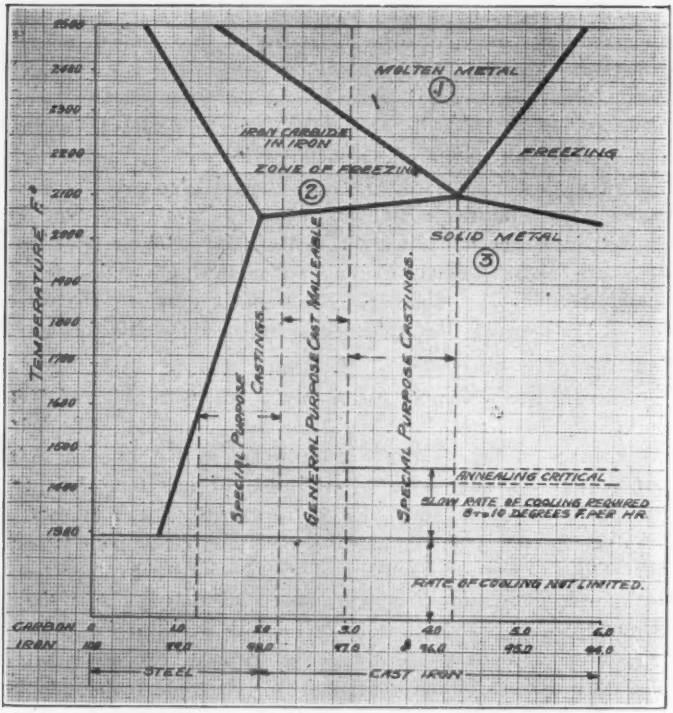

FIG. 8—EFFECT OF TEMPERATURE AND CARBON UPON PURE IRON AFTER EQUILIBRIUM EXISTS

which electric heat offers the malleable iron foundrymen, we will review first the general nature of malleable iron and the laws governing its production. We must also show that the use of electric heat promises a malleable iron better suited to meet the requirements in its present field of application and if possible at a lower cost than can be had by present fuel-fired processes. If this can be done, will electric heat create a "super" malleable, the improved characteristics and uniformity of which will encourage its broader use, and at a less cost replace satisfactorily certain alloy or steel castings?

The present day malleable iron is made from pig iron of

suitable composition for the purpose. In the pig iron are pure iron and certain elements; namely, carbon, silicon, sulphur, phosphorus and manganese. These elements form different chemical compounds with each other and with iron under different conditions, the combinations possessing very different physical characteristics. For example, pure iron is so soft that it can scarcely be machined without the chips shearing or tearing off in advance of the cutting tool, leaving a rough machined surface. On the other hand, soft iron combined with carbon in the ratio of 93.33 to 6.67, gives iron-carbide, a material as hard as any known compound of iron.

Curves Show Effect of Temperature on Various Compositions

Referring to the curves shown in Fig. 8 we have shown the general laws governing the various proportions of iron and carbon with variation of temperature. This temperature is that at which stable equilibrium exists for the particular ratio of iron to carbon; in other words the chart has nothing to do with transitory states of formation of carbides of iron. It is first observed that pure iron when combined with 1 to 1.75 per cent of carbon is known as steel, while pure iron combined with 1.75 to 6.67 per cent of carbon is known as cast iron. When a casting carrying a certain percentage of carbon is subjected to heat treatment without melting, chemical changes may result in setting free a part of the carbon content as free carbon or graphite, leaving the remaining part in the combined state. Fig. 8 shows general purpose malleable iron carrying from about 2.25 to 3.00 per cent carbon. This is the only phase of malleable this paper will consider.

It will be noted that these compounds of iron and carbon are liquid at about 2280 to 2380 degrees Fahr. and solidify at about 2060 to 2080 degrees Fahr. The temperature range in which chemical changes go on to convert combined carbon to free carbon is about 1420 to 1460 degrees Fahr. This is called the critical stage, where carbon may exist either free or combined. Time is required for the consummation of the chemical change in the critical force, so that for a given degree of free

carbon content certain minimum time is required, about 40 hours.

At about 1300 degrees Fahr. and below the proportion of combined and free carbon can change little, if any. In order to pass to this state of equilibrium from that in the critical zone, time must elapse during the change in temperature which carries the charge from a higher to a lower zone. For malleable it has

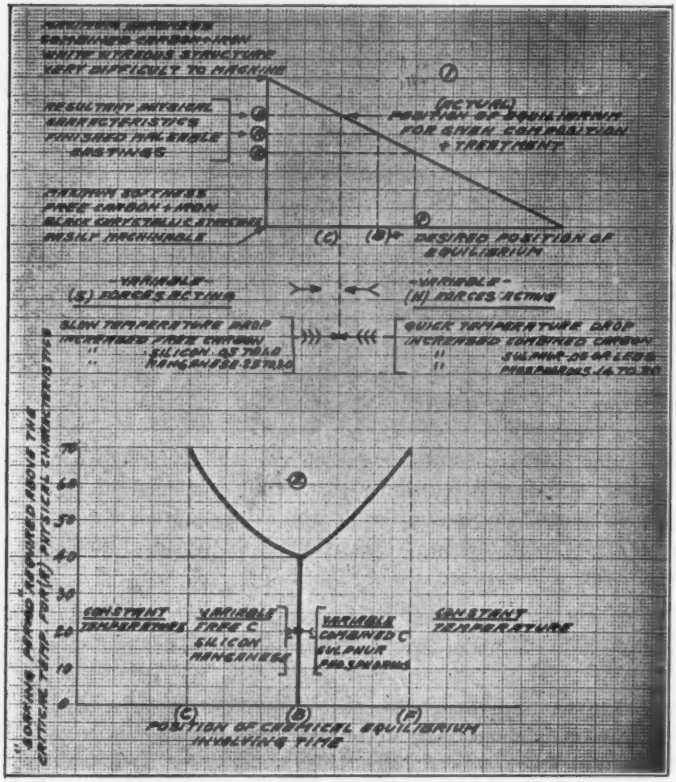

FIG. 9—GENERAL LAWS CONTROLLING THE RESULTANT PHYSICAL CHARACTERISTICS AND PROPERTIES OF MALLEABLE CAST IRON

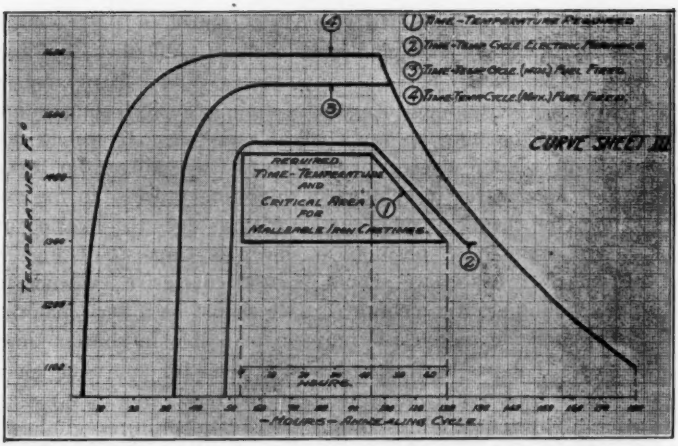
CURVE SHEET III
REQUIRED TIME-TEMPERATURE AND CRITICAL AREA FOR MALLEABLE IRON CASTINGS.
TEMPERATURE F°
HOURS — ANNEALING CYCLE.

FIG. 10—COMPARATIVE ANNEALING CYCLES OF MALLEABLE CAST IRON SHOWING THE ADVANTAGE OF ELECTRIC CONTROL

been found that this time rate of temperature change must not exceed 8 to 10 degrees per hour. The foregoing then shows the relations of time, temperature and carbon and their effect on iron combinations.

In Fig. 9, Curve 1 is shown the combined effect of time, carbon, silicon, manganese, sulphur and phosphorus, upon iron, and the physical characteristics imparted to it by the combinations within the limits in value of the variables employed in the production of malleable iron. It is seen that in slow cooling, silicon and manganese act in general in the direction of giving softness, free carbon, and a black crystalline structure, which is easily machinable. On the contrary, in quick cooling, sulphur and phosphorus work toward hardness, combined carbon, and white vitreous structure which machines with difficulty.

We see in Fig. 9 Curve 2 the effect on time when the temperature is held constant and the "impurities" are varied between limits as shown in Curve 1. Here we see the need for close control of the proportion of impurities in order to conserve time.

Here it may as well be pointed out that the electric melting

furnace is best equipped to give close control of the chemical composition of the raw malleable casting. Whether the iron be melted electrically is not so important as that it be refined or brought to a certain uniform and definite chemical composition for the pouring into the raw malleable casting. If we do not start with a high degree of uniformity we will suffer to a more or less degree in subsequent annealing process, to the extent that the chemical composition varies as does the location of *C* and *F* from the *B* position, as shown in Curve 2 of Fig. 9. The study of this curve should furnish conclusive evidence to prove that the electric melting furnace should be a very material aid in producing high class, uniform malleable in shorter time.

Fig. 10 shows how electric heat applied for annealing gives advantages of lower temperatures and shortened annealing cycles. Lowering of temperatures means lesser temperatures gradients when passing from the outside to inside of charge, and increased thermal efficiency by lowering the loss through furnace walls. Close temperature regulation, Curve 2, gives the ability to follow much more closely the time temperature characteristic, Curve 1, required without falling below it. A comparison of Curves 2, 3 and 4 show the magnitude of the advantage offered by the electric annealing furnace.

Charges Should Be Subdivided When Practical

In these curves of practical operating ovens it may be noted that the time of heating the charge requires from 25 to 50 hours. This is due to the fact that designs of ovens do not allow for subdivision of the charge. This should be done so far as it is practical, to reduce the temperature gradient from outside to inside of the charge. This secures uniformity and shortens the time in hours of cooling in proportion to the value of temperature gradient divided by 8. Hence, if the temperature gradient were 200 degrees, we must lengthen our time of cooling

$$\frac{200}{8} = 25 \text{ hours},$$

or, in other words, carry our cooling down to 1100 degrees

Fahr., instead of only 1300 degrees Fahr. The same lag in heating up will be observed, and though it does not effect the quality of the charge it does lengthen the annealing cycle, which means increased cost, increased time or greater floor space for same production and less uniformity of product.

Without going into details of annealing oven designs, it is evident, however, that the design should be such as to reduce the length of path by which heat is conducted from outside to inside of charge to the minimum practical. The design employed for which the electric characteristic, Curve 2, Fig. 10, is drawn allows a time for heating up of seven hours, and a low gradient of about 30 or 40 degree Fahr. maximum between outside and inside of charge. The charge is annealed without packing in a container, so that higher thermal efficiency results along with no oxidation of the charge, due to the inert atmosphere of the electric annealing oven. Tabulating the results of Fig. 10 we obtain Table I.

TABLE I

COMPARISON OF FUEL-FIRED AND ELECTRIC HEATING PRACTICE

Total time in cycle, hours	Heating time hours	Holding temperature hours	degrees Fahr.	Cooling hours	degrees Fahr.
Present Practice, Fuel-Fired Equipment					
182	48	72	1600	62	1100
118	25	48	1550	45	1100
Proposed Practice, Electric Oven—Charge Subdivided					
70	7	48	1460	15	1250
60	7	40	1460	13	1250

Here then the electric annealing oven offers a short anneal when properly designed to give the effect of subdividing the present-day charge, whether it be accomplished by replacing the large oven with a battery of smaller ones or by the tunnel oven or conveyor type. Every evidence exists to show that better quality may be produced with an anneal in 60 hours in the properly arranged electric oven, against the 120-hour anneal of present day fuel-fired ovens.

Information Developed from Actual Furnace Tests

Thus far our results have been more or less theoretical. Let us see what has been accomplished by the fuel-fired proc-

esses in the past, and finally what tests on electric annealing ovens show. In Fig. 11 we have plotted past performance against time. We note from 1903 to 1911 little change in direction of progress. From 1911 to 1915 a marked advance occurred. We find this was due to a campaign of introduction of improved ways and means for the control of conditions

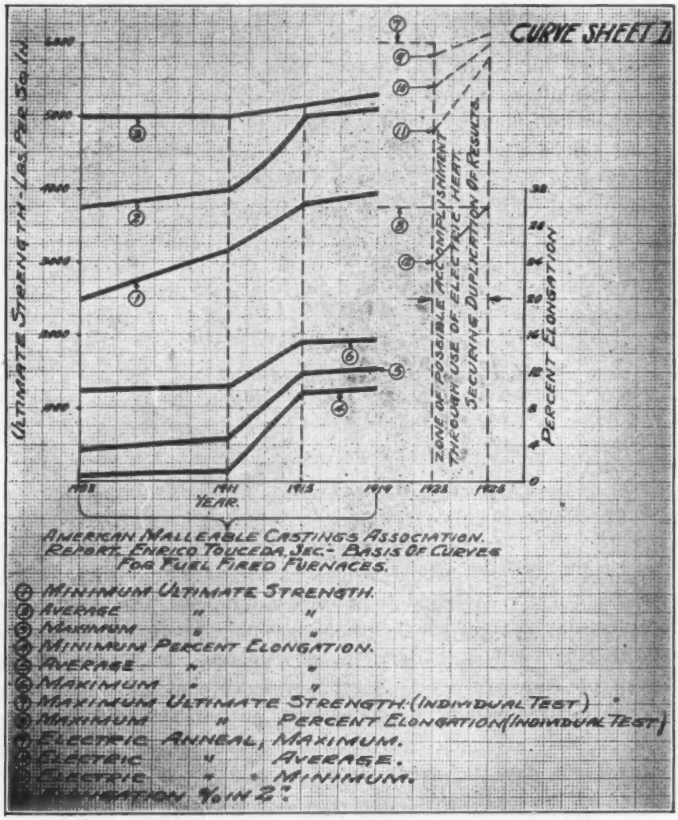
CURVE SHEET 1
ULTIMATE STRENGTH-LBS. PER SQ. IN.
PERCENT ELONGATION
ZONE OF POSSIBLE ACCOMPLISHMENT THROUGH USE OF ELECTRIC HEAT. SECURING DUPLICATION OF RESULTS.
1903
1911
1913
1919
1923
1925
YEAR.
AMERICAN MALLEABLE CASTINGS ASSOCIATION.
REPORT. ENRICO TOLEDA, SEC.- BASIS OF CURVES FOR FUEL FIRED FURNACES.
① MINIMUM ULTIMATE STRENGTH.
② AVERAGE " "
③ MAXIMUM " "
④ MINIMUM PERCENT ELONGATION.
⑤ AVERAGE " "
⑥ MAXIMUM " "
⑦ MAXIMUM ULTIMATE STRENGTH (INDIVIDUAL TEST)
⑧ MAXIMUM " PERCENT ELONGATION (INDIVIDUAL TEST)
⑨ ELECTRIC ANNEAL, MAXIMUM.
⑩ ELECTRIC " AVERAGE.
⑪ ELECTRIC " MINIMUM.
⑫ ELONGATION % IN 2".

FIG. 11—RESULTS OF PHYSICAL CHARACTERISTICS PREDICTED FOR MALLEABLE IRON WHEN MANUFACTURED IN THE ELECTRIC FURNACE

known to be necessary for the best product. In 1915 the average had about reached the best individual result obtained in 1911. Curves 1 and 3, also 4 and 6 converge, which indicate closer control and greater uniformity of conditions and results.

May we not expect history to repeat itself? Through the use of the electric furnace we get products shown by Curves 10 and 12 and with a variation of that between Curves 9 and 11. Is it not logical to expect that by 1925, perhaps, that the use of the electric furnace will allow us to produce regularly, without fail, results equal to the individual values of Curves 7 and 8, or, in other words, raise the average to the maximum now keen for malleable characteristics. Some results obtained in electrically annealing castings made in the fuel-fired melting furnace are shown in Table II.

TABLE II

RESULTS OF ANNEALING CASTINGS IN ELECTRIC FURNACE

				Annealed casting			
Length of anneal, hours	—Hard carbon per cent	Iron— silicon per cent	Diameter of bar, inches	Yield point pounds per square inch	Ultimate strength pounds per square inch	Elongation per cent	Reduction in area per cent
42	2.45	0.81	0.635	39,184	54,763	9	...
42	2.56	1.00	0.640	33,883	47,802	7	...
42	2.56	0.83	0.640	34,813	53,010	8.5	...
42	2.42	0.71	0.635	35,550	58,558	8.5	...
50	2.42	0.71	0.625	35,110	52,323	24	10.3

In Table III are collected reports of the test average and individual results of producing malleable in the fuel fired furnace; both melting and annealing. Due to the wide range in results shown, the table is in itself a good exposition of the

TABLE III

RESULTS OF PRODUCING MALLEABLE IN A FUEL-FIRED FURNACE—MELTING AND ANNEALING

Standard anneal hours	Number of samples	Average carbon per cent	Minimum carbon per cent	Maximum carbon per cent	Ultimate strength pounds per square inch	Average elongation per cent	Range of elongation per cent
120	40	1.51	0.72	2.03	52,000	22	25-20
200	1	2.49	...	...	56,500	18	....
120	1	Individual result			85,000	5	....
120	1	Individual result			59,681	21.5	....
Average results reported by American Malleable Castings association.....					51,000	12.5	....

inability to control the various factors with any great precision. Otherwise, the average values would not depart so greatly from the individual results.

Accurate Duplication of Results Made Possible

We know that the electric furnace is in essence a tool which allows indefinite duplication of a given heating formula. Therefore, it is the best known tool not only to secure uniformly good results for a given set of conditions, but also to lead to the adoption of conditions that in themselves make for better results.

In conclusion the foregoing should be convincing evidence that electric heating holds much promise for advance in the quality of malleable iron. It is believed that advantages of its use will make for a better product at a less overall cost, and that the employment of the electric current by the foundry, either for melting or for annealing, will bring gratifying results. Perhaps it is well to start with electric annealing; but in order to get the greatest benefit from either, at least the refining of the melted charge should accompany electric annealing.

In other words, for the best product; 1. The melting may be done with fuel and the molten charge refined by electric furnace; or 2. and preferable for quality, the whole melting operation should be electric. Having thus produced a superior hard casting, we may get the best annealed casting 1. by heating to the annealing point by fuel-fired furnace, and then holding or soaking in the electric furnace, and finally cooling under electric control; 2. preferably again for the sake of quality, the whole anneal should be carried out with electric heat.

Charge Should Heat Within Given Time

In any case the annealing ovens should be of such size or arrangement that the charge will heat from the outside to the center in six or seven hours. This in itself will make for uniformity and overall economy. Therefore, without saying anything definite as regards the design of electrically equipped ovens than that above, the writer confidently predicts that if electric heat is made use of by this industry in the general method out-

lined, that it will rapidly come to be recognized as the standard way of producing the malleable cast iron parts.

Before closing the author wants to touch briefly upon the overall cost of metal heating when done electrically. Let us see what the cost of the heat treating operation really is, in proportion to the total cost of manufacture. A few representative products in Table IV run about as follows: Electricity 1 cent per kilowatt-hour, oil 5 cents per gallon.

These average about 0.86 per cent of factory cost for electric power and about 0.29 per cent for oil,—the difference in sell-

TABLE IV

COMPARATIVE COST OF HEATING BY ELECTRICITY AND OIL

Part heated	Factory cost	Total cost for heat treating electric	Cost for heat treating oil	Power cost for heat treating electric	Factory cost for heat oil per cent	Factory cost for heat electric per cent
1—Die	$1,380	$13.50	$1.25	$4.16	0.10	0.30
2—Die	1,138	12.00	1.11	3.70	0.11	0.32
3—Die	638	5.03	0.45	1.50	0.07	0.23
4—Die	782	9.45	0.90	2.92	0.12	0.37
5—Die	795	10.53	0.73	2.43	0.14	0.43
6—Die	785	8.66	0.80	2.67	0.10	0.30
7—Gear	234	13.00	1.11	3.70	0.50	1.50
8—Gear	263	15.00	1.33	4.44	0.54	1.70
9—Gear	338	21.00	1.87	6.25	0.60	1.80
10—Gear	391	26.00	2.28	7.60	0.63	1.90
11—Gear die block	110	1.75	0.19	0.65	0.20	0.60

ing cost, then, being only 0.0057, or about 6/1000 of the cost of production. Hence we equalize costs if we realize an advantage of 6/1000 over oil heating in the electric process. Whether that comes from increased quality, increased production, decreased floor space, better working conditions, ability to duplicate results, temperature control, uniformity of product, decrease in rejects, decrease in labor or some other element entering into the total cost of production, matters not. Fortunately for electric heating, when these conditions are all taken at their increased value, due to the electric process, the balance is in increasing numbers found to be on the side of the electric.

Furnaces Must Be Designed for Particular Duty

Some who have made a superficial study of electric furnace problems do not appreciate that it is one worthy the ef-

fort of the most skillful and resourceful engineer. Many do not understand that a furnace must be designed for its particular duty with as much care and in such variety as machine tools. It has been assumed in the past many times that a furnace was simply a pile of bricks with a sufficient source of heat within it. Hence heat energy application in this country heretofore has been largely the composite result of promotion and advertisement, rather than of engineering.

We have had fuel oil advocates, gas burning experts, powdered coal enthusiasts, fuel oil promoters, and perhaps electric furnace salesmen, etc., but have until recently lacked the competent furnace engineer familiar with all types of furnaces and who could sit as a court of appeals and give unbiased decision regarding the true economic value of various furnace designs for specific applications.

Finally, it may be said that when the balance in overall foundry cost is decidedly on the side of electric heating, then we contend that electricity be given its rightful place. On the other hand, when local conditions and environment make for advantageous use of fuel heat, we cheerfully and just as earnestly endorse the use of fuel heat.

Electric Cranes in Foundry Service

By A. H. McDougall, Harvey, Ill.

The operation of a foundry is largely a problem of handling material. The method by which it is accomplished affects the cost of the finished product.

From the time the material, in the form of pig iron, scrap, coke, sand, and crushed stone, arrives in the foundry yard until the finished product is delivered to the shipping platform a continuous process of raising and moving material is taking place. Of all the machinery and appliances used in foundries electric traveling cranes effect the greatest saving in the cost of operation. This is due to the fact that an electric crane has three motions, making every square foot under the runway accessible to crane service. A conveyor or industrial track, on the other hand, serves only a narrow path and a jib crane only the area of a circle.

Let us deal first with the handling of the raw materials in the yard, which may be either an open yard or a covered material bay—preferably the latter. This is somewhat dependent upon prevailing climatic conditions. The storage yard should be served by a 10-ton crane having a span of about 75 feet. The trolley should be designed to operate a clam-shell bucket for unloading coke and sand and loading foundry refuse, and an electric magnet for unloading pig iron and scrap. The magnet also should be used for handling a drop weight for breaking up scrap. If a new foundry is being planned, the charging floor should be designed so that it also can be served by the crane, as shown in Fig. 1. However, this is only recommended for emergency use in case of a temporary shutdown of the elevators, which normally should be depended upon to take all material to the charging floor.

The operating speeds of the crane should be

	Feet per minute
Bridge travel	300
Hoist, full load	30
Trolley travel	125 to 150

The trolley should be designed so that the magnet and bucket drums are independent of each other and are operated

FIG. 1—A 10-TON CRANE IN A FOUNDRY MATERIAL STORAGE BUILDING EQUIPPED WITH MAGNET FOR HANDLING PIG IRON AND SCRAP. THE CRANE IS CAPABLE OF UNLOADING 10 CARLOADS OF PIG IRON DAILY

by separate motors and controllers. The operator's cage should be closed and designed so as to be well lighted and heated, as illustrated in Fig. 2.

However, it should be stated that in a large degree such a crane can be replaced in smaller foundries by a standard three-motor yard crane equipped with a magnet winding drum for handling magnet cable so that an electric magnet can be used. The magnet can be readily removed and a single line grab bucket attached. This plan works out well, except that some time is lost in making the change.

How To Estimate Horsepower Required

To estimate the amount of horsepower required to operate a crane at the speeds specified above, one should first consider the travel of the bridge. Add the weight of the crane in tons to the weight of the maximum load and multiply this sum by the tractive effort of the wheels which may be assumed to be 60 pounds per ton. The result then should be multiplied by the speed in feet per minute, and this will give the number of foot pounds required. Foot pounds are converted to horsepower by dividing by 33,000. The horsepower required to rack the trolley is obtained in the same way except that 40 pounds per ton instead of 60 is used as the tractive effort. In determining the horsepower required for hoisting, it is safe to allow one horsepower for hoisting one ton 10 feet per minute. These data make it easy to check up the power supply and to establish the peak loads. As a general proposition not more than two operations are effective at one time.

Let us now consider the main molding bay. In a foundry having a daily output of from 30 to 40 tons per day, the crane should have a span of not less than 60 feet. The span often is made too short, or in other words, the molding bay is too narrow. The main crane for heavy molding, pouring, and shaking out should have a capacity of not less than 15 tons, and should be motored to provide a bridge travel speed of 300 feet per minute, a full-load hoisting speed of 25 feet per minute, and a trolley travel of 125 to 150 feet per minute. These speeds are for full load. A 10-ton and a 5-

ton crane having high operating speeds should be installed on the same runway. The trolleys for these cranes should be so designed that all the gears are enclosed in dust-proof cases and run in oil, as shown in Fig. 3. This not only will greatly increase the life of the mechanism but will conform to all safety requirements. The design should also be such that every part is readily accessible for maintenance and the parts are easy to handle.

Traveling electric wall cranes sometimes are used, but it must be remembered that they impose severe strains on

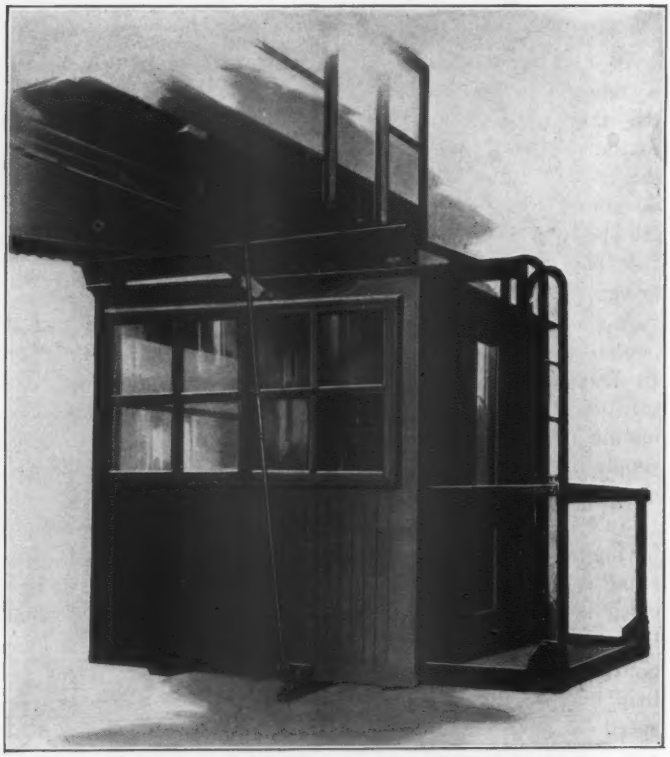

FIG. 2—ENCLOSED CRANE CAGE

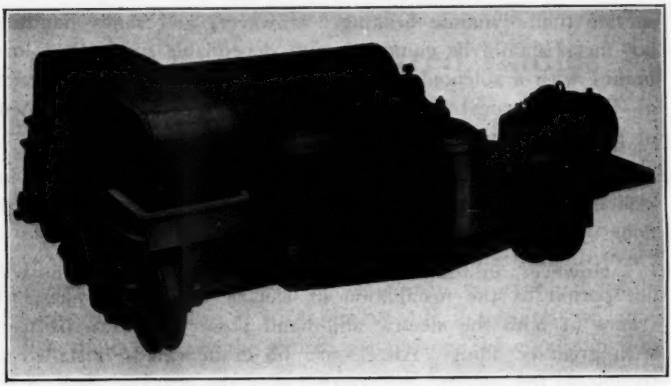

FIG. 3—TWO MOTOR CRANE TROLLEY; CAPACITY 20 TONS

the building columns, necessitating expensive steel construction to overcome the reactions. Because of the limited area of molding floor served by these wall cranes, the work is more efficiently accomplished by the high speed, electric traveling cranes.

Alternating Current Motors Preferred

It has been found that in foundry service, all things considered, alternating current is much more applicable than direct current. The alternating current slip-ring motors operate in the dusty atmosphere of a foundry with little or no attention aside from lubrication, whereas under the same conditions, direct current motors, because of the commutator, have to be given at least weekly attention. This necessitates taking out the armature and truing up the commutator by expensive maintenance men, generally at an overtime rate.

The manufacturers of electrical controllers, now have developed for foundry service the creeping speed control which gives 90 per cent control on the first point, and has not the disadvantage of accelerating on light loads and injuring delicate molds. They also have developed the two-torque, or double load, which is proving more satisfactory for speed and control in foundry

service than dynamic braking. However, all cranes handling hot metal should be equipped with dependable mechanical load brakes with a solenoid brake on the hoist motor, as the action of the mechanical brake is always positive and the element of possible chance of failure of the dynamic brake is absent.

Cranes of short span and light capacity should be installed in the side bays and core rooms. These should be floor operated, for ready use by the molder and helper.

However, in foundries where the buildings or output will not permit of the installation of electric traveling cranes, jib cranes of both the electric and hand power type can be used with great economy. An electric jib crane can be installed at the cupola for molding and pouring even the heaviest work. A jib crane of the top-braced type also can be used to great advantage in the yard for unloading and breaking scrap and for loading finished castings.

For foundries operating on light work such as stove plate, agricultural castings, etc., an overhead trolley system has been developed on which a right-angle turn can be made in a space of 18 inches. These systems are invaluable for distributing flasks and supplies, delivering molten metal, collecting castings from the floors and delivering them to the cleaning room, and for serving the brass furnaces when situated in a corner of the main foundry. With this system a small room can be served, the trolley passing out and in the door on the track. These systems should be provided with positive switches and turntables that embody all safety features. The trolley must be of high-grade design and material, with ball bearing axles so they will travel easily by pushing or pulling on the load.

The Design of Geared Ladles

By A. W. Gregg, Harvey, Ill.

The design of geared ladles merits careful study and presents more engineering problems than casual and superficial attention would lead one to suspect. Foundry methods and equipment have been undergoing great changes during the last 10 years, but regardless of what developments may be expected in the foundry of the future, it is reasonably safe to predict that ladles will be used to carry the molten metal from the cupola or furnace to the molds. The majority of ladles in use are geared ladles, the exceptions being bottom-tap ladles for large steel castings and hand and shank ladles for small castings of all kinds.

Unless a geared ladle is properly designed and properly cared for, it is an endless source of trouble and danger in the foundry. In the first place it is used daily. It is subjected to heat from the metal and from the ladle heater which causes expansion of bail and bowl, followed by contraction on cooling. With most styles of geared ladles the expansion and contraction seriously affect the alignment of the gearing. In many foundries the lubrication of ladle gears and trunnions receives little attention, and this neglect results in excessive wear. For a time this causes hard turning and later too much play in the gearing. Unless grease cups and oil holes are located so that the lubricant gets to the bearings and gears properly and in sufficient quantity, the ladle gearing will suffer, no matter how much care is exercised.

Lost Motion Cause of Accident

When lost motion is present in the gearing a dangerous drop of the ladle occurs during pouring, caused by the flow of the metal. This usually results in a splash of molten metal which may cause serious injury to several men. On the other hand, if the gears are too tight and bind, pouring is an arduous task which cannot be properly performed, and cold-shut or misrun castings result.

The important features of geared ladle design fall under the following classifications:

1. Type of gearing
2. Gear ratio
3. Design of housing
4. Location and type of trunnion

Geared ladles usually are classified according to their type of gearing. This and the gear housing are the features

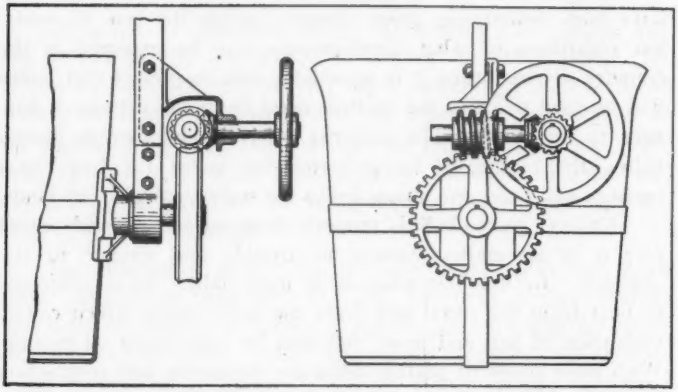

FIG. 1—ARRANGEMENT OF WORM GEARING ON FOUNDRY LADLE

of greatest interest and importance. There are three types to be considered, namely, worm, spur and helical-worm.

The first type of gearing to be applied to a ladle was the worm, which is illustrated in Fig. 1. Worm gearing has been used on ladles in this country for from 70 to 80 years. The principal improvement which has been made in this time has been the substitution of cut tooth gears and cut worms for cast. The gearing is compact in design and is fitted with bevel pinions which allow the extension of the handwheel shaft at right angles. When the gearing is in good condition and perfect alignment it permits a smooth and easy turning action which affords good control of the stream of metal flowing from the ladle to the mold. One of the greatest advantages of worm gearing lies in the fact that it is self-locking. The disadvan-

tages are its tendency to bind unless in perfect condition; the fact that it is relatively slow; and the low efficiency of the gear train which makes it harder to turn than the other types. By far the greatest number of ladles at present in use in this country have worm gearing.

Advantages of Spur-Geared Ladle

The spur-geared type is illustrated in Fig. 2. It was introduced in this country about 30 years ago in the pipe found-

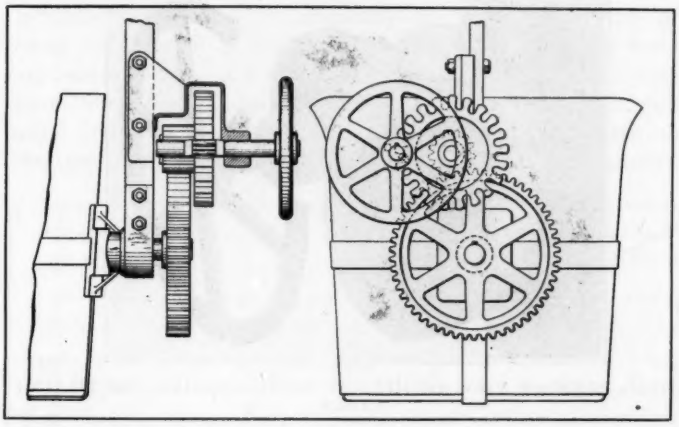

FIG. 2—LADLE EQUIPPED WITH TYPICAL SPUR GEARING

ries, where a faster operating ladle than worm gearing permitted was desired. Where fast pouring is required this gearing still is largely used. It has a high gear efficiency and less tendency to bind than worm gearing. One of its disadvantages is that it tips the ladle in a slightly jerky manner due to the finger pinion which is necessary to get gear reduction with compact design. This jerky action causes uneven pouring and a tendency to form a skull on the sides of the pouring lip as the metal washes up and down. However, the most serious trouble with the spur gearing lies in the fact that it is not self-locking. The safety laws of at least three states now forbid its

installation on ladles and several other states are threatening to follow suit.

Helical-Worm Gearing

The third type of gearing, known as the helical-worm, is illustrated in Fig. 3. This is a recent development and eliminates many of the troubles found in the two older types. The most important feature of this gear mechanism lies in the fact that (unlike the first two types described) the housing is mounted

FIG. 3—PHANTOM VIEW OF HELICAL WORM GEARING FOR TILTING LADLE

on the trunnion and has no attachment to the bail except through a sliding support. This results in making the tilting mechanism an independent unit, and the alignment of the gears is not affected by distortion of bail or bowl or by wear on the trunnion journals.

The gear combination has an efficiency about 33 per cent higher than that of the worm and is self-locking. Because of the balanced thrust obtained through the helical gears the turning action is smooth and requires little power. The helical gearing permits a wide range of tipping speeds to be obtained, by interchanging the helical gearing with another set of different helix angles.

Fig. 4 shows the gear ratios ordinarily used for ladles of

from 1500 to 40,000 pounds capacity for worm and helical-worm types of gearing. The gear ratio is determined primarily by the size of the ladle and the desired speed of pouring. The gearing ratio as used in Fig. 4 is the number of revolutions of the handwheel for one complete revolution of the ladle. Four different ratios are shown for each size of ladle with the helical gearing and one ratio for each size with worm.

Location of Trunnion Is Important

The location of the trunnion is a matter of great importance in the design of any ladle. The customary practice is to place the trunnion at practically the center of gravity of metal and ladle in an upright position. Fig. 5 shows the turning moments of a 10-ton ladle at various angles. The curves show the moments due to friction, eccentricity of ladle and metal and also the total moment. These curves are based on the results obtained in a series of tests conducted to determine

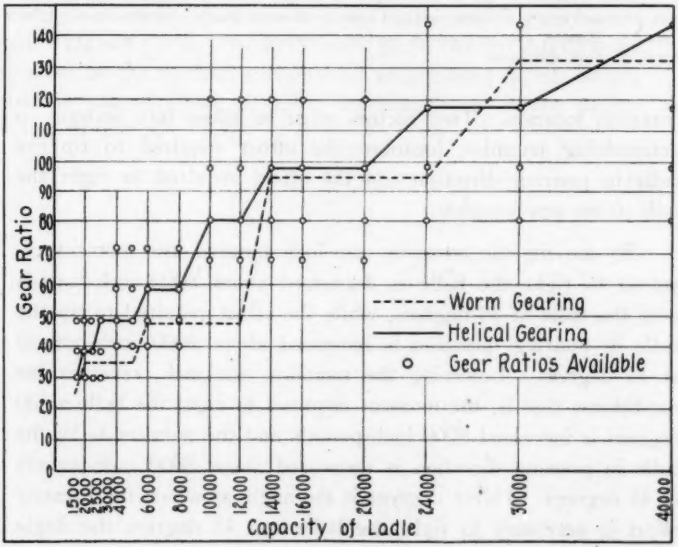

FIG. 4—GEAR RATIOS FOR LADLES OF FROM 1500 TO 40,000 POUNDS CAPACITY

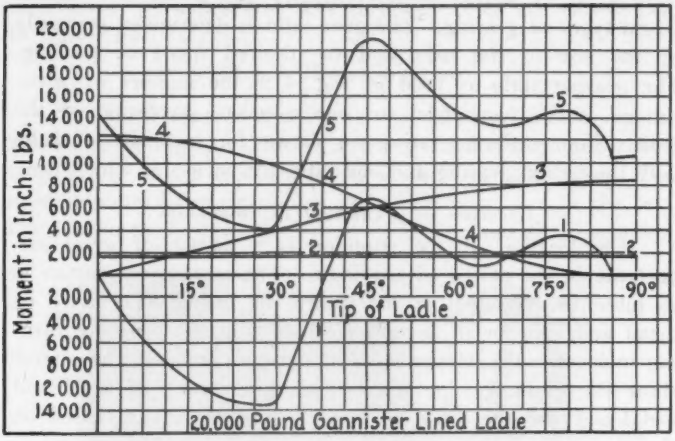

FIG. 5—CURVES SHOWING TURNING MOMENT OF A 10-TON LADLE
Curve 1—Moment due to eccentricity of metal; Curve 2—Moment due to trunnion friction (weight of ladle only); Curve 3—Moment due to eccentricity of ladle; Curve 4—Moment due to trunnion friction (weight of metal only); and Curve 5—Total of above moments.

trunnion location. Two factors must be taken into account in determining trunnion location—the effort required to tip the ladle in pouring direction and the effort required to right the ladle from any position.

By moving the trunnion one inch upward, the moment required to right the ladle is decreased about 8000 inch-pounds with the ladle at 30 degrees, while the effort required to tip the ladle in pouring direction is increased about 8000 inch-pounds at 45 degrees. Lowering the trunnion one inch, reverses the conditions; that is, the moment required to right the ladle at 30 degrees is increased 8000 inch-pounds and the moment to tip the ladle in pouring direction is decreased about 8000 inch-pounds at 45 degrees. Thirty degrees is the angle at which the greatest effort is necessary to right the ladle and 45 degrees the angle at which the greatest effort is required to tilt it in pouring direction.

Force Required to Turn Handwheel

The force required on the handwheel for the ladle illustrated may be calculated for any angle by dividing the moment at that angle by the gearing constant shown. This constant, which is known as the moment ratio, is 530 for helical and spur gearing, and 400 for worm gearing. It is derived by taking into account the size of the handwheel, the gearing efficiency and the gear ratio. For example; at 45 degrees for a 10-ton helical geared ladle, the total moment is 21,000 inch-pounds and the force required on the hand wheel is $\frac{21000}{530}$ or approximately 40 pounds. (This calculation is based on dry bearings).

Other points of importance in ladle design are the types of trunnion and bail. Both should be of rolled mild steel and in calculating the size a factor of safety of about 10 should be used.

Foundrymen have been prone to consider ladle trouble a necessary evil of the foundry business and something to be endured. This is not true. Proper care and proper design will do away with most of the troubles encountered with geared ladles. Safety should be placed above all other considerations in the design and use of ladles.

Heating Metal Patterns Electrically

By C. A. Cremer, Pittsburgh

When moist molding sand is rammed up around a cold metal pattern a thin film of moisture collects on the surface of the pattern so that when it is withdrawn from the mold, there is a tendency for some of the sand to adhere to it. This causes a roughening of the surface of the mold so that it will not yield a clean smooth casting. For many classes of work it is essential that the castings be clean and smooth, and therefore, means must be used to overcome this tendency of the sand to stick to the pattern.

There are two ways of preventing this trouble; one is to dust a parting compound over the pattern and the other is to heat the pattern.

Using Parting Compounds on Mold

If a parting compound is used it must be applied frequently, at least for every second or third mold. This takes a certain amount of time, and furthermore it may be done carelessly, with the result that parts of the mold may not be covered, in which case imperfect molds would result. This imperfect covering of the mold would be especially likely to happen in the case of intricate patterns or patterns with surfaces nearly perpendicular to the plane of the mold, to which surfaces the compound might not readily adhere.

Proper heating of the pattern, however, insures that all parts are equally prepared to prevent the sticking of particles of sand and eliminates the time required for applying the compound.

The most common methods of heating metal patterns are by means of a gas flame or a kerosene torch. The gas flame is more readily applicable to stationary molding machines, but cannot be conveniently used for portable molding machines, which are moved along the foundry floor as the making of

molds progresses. In such cases the kerosene torch, or a tin can filled with sand on which kerosene has been poured, is more frequently used.

The disadvantages of such crude heating methods must surely be apparent to any one who has had experience with them. In the case of molding machines heated with a gas flame the usual method is to maintain a gas flame within the frame work of the machine in the space under the pattern plate. It is difficult to keep the flame low enough so that the pattern will not be overheated. Furthermore, the heat from a gas flame is localized, whereas what is wanted is a uniformly distributed heat so that all parts of the pattern will be equally heated. To overcome these difficulties with low flame and localized heat, it is customary to burn a larger flame than is actually required to produce the necessary heat for the pattern and to locate that flame at a greater distance from the pattern plate. This, of course, is an inefficient arrangement since a large part of the heat is wasted. It has an added disadvantage in that the gas fumes are unpleasant for the workmen and in the summer time the heat is objectionable. Also with this method of heating variable gas pressure makes frequent attention necessary, and in some sections of the country where there is a scarcity of gas in cold weather, there may be no gas pressure at all at times when the use of heat is most necessary.

Using Kerosene To Heat Pattern

The objections to the use of kerosene torches or tin cans filled with sand saturated with kerosene—which are said by some who have used them to be better than torches—must be even more obvious than the objections to gas flames. Aside from all difficulties with the molds being too hot or too cold, necessity for cleaning and refilling the torches, and general inconvenience, messiness, and crudity of the method, the fact that there is a constant emission of evil smelling fumes right into the faces of the men working over the molds has been sufficient reason, in at least one case, for the manager of the plant to apply a more modern method of heating the patterns.

At the West Newton plant of the U. S. Radiator Corp. a considerable number of metal patterns are used from which molds are made continually throughout the day. It had been the practice at this plant to warm the patterns by means of kerosene torches to prevent the sand from sticking to them, since it was essential that the molds be perfect. But warming the patterns with kerosene torches was a dirty, smoky operation and not at all popular with the workmen.

Experiments With Electric Heat

The manager of the plant conceived the idea of applying electric heaters to the patterns, and made preliminary experiments with heating elements from electric sad irons. The shape of these elements prevented their most efficient application to the pattern and they did not stand up well, but the result indicated that electric heating of metal patterns was practicable.

While in search of more suitable heating elements the manager heard of the steelclad type of heater. Two of these heaters were secured and applied to the patterns. The results were so satisfactory that now about 15 patterns are equipped with similar electric heaters.

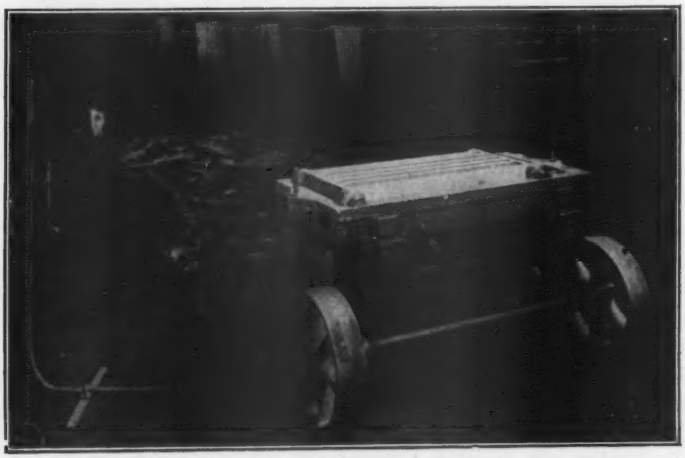

FIG. 1—PORTABLE MOLDING MACHINE EQUIPPED WITH HEATER

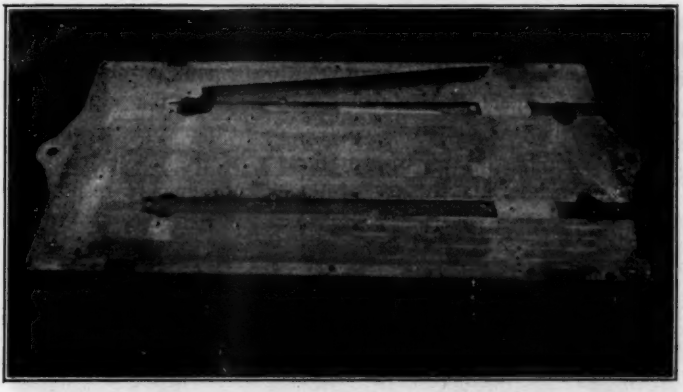

FIG. 2—MACHINE WITH ONE HEATER REMOVED TO SHOW METHOD OF MOUNTING

Fig. 1 shows the general shape of the pattern with its supporting carriage. The power is supplied from an ordinary lamp socket through a flexible cord which is attached to the pattern carriage. In moderately cold weather the heat is used intermittently as the need for it appears, but in extremely cold weather, the heat is left on continuously while the pattern is in use. The capacity of the heaters is 600 watts at 110 volts, and the temperature to which the patterns are heated is approximately 90 or 100 degrees Fahr.

Applying Heater to the Pattern

Fig. 2 shows how the heaters are applied. Standard steel-clad heaters of the narrow type which are in the form of a long flat strip approximately 20 inches long, 1 1/8 inches wide and 1/8 inch thick are laid in grooves cut in the face of a cast iron plate which forms the top of the carriage. The heater terminals project downward through holes drilled through this plate and are wired to a socket on the side of the carriage. The upper surfaces of the heaters, which are perfectly flat, are flush with the upper surface of the plate, so that when the pattern plate is laid on the top of the carriage the heaters are in contact with

it. With the pattern plate in place, and fastened with suitable bolts or screws, the assembly is similar to the construction of a modern electric iron—the heating elements being firmly clamped between two metal plates so that the heat from the heating elements will be transmitted by conduction to the working surface. This enables the heaters to operate at a relatively low temperature, and makes the surface of the pattern quickly responsive to the application of heat.

Some of these pattern carriages have been equipped with electric heaters mounted in the space below the pattern plate, but not in contact with it, so that the heat is transmitted to the plate by radiation instead of conduction. This method is not so efficient in utilization of the heat and results in slightly greater power consumption and slower heating, but is otherwise satisfactory. It is a cheaper method of installing the heaters and in some cases it may be the most practicable method.

The manager of the plant where these electrically heated patterns are in daily use has reported that the use of electric heat has been cheaper than the use of the kerosene torches, besides being more satisfactory in other ways, particularly with respect to the absence of obnoxious smoke and fumes.

At about the same time that electric heaters were being applied to the radiator patterns, another manufacturer installed electric heaters of the same type in a molding machine. As in the case of the radiator patterns the method of applying the heaters consisted essentially in arranging and supporting them so that they would be in contact with the under side of the pattern plate below the thickest part of the pattern. The heaters were not attached to the pattern plate, but were supported on angles attached to the frame of the machine, and therefore their presence did not interfere with the changing of the pattern whenever required.

The heaters are of the steelclad type which consist of slotted ribbon heating elements of high resistance, heat resisting alloy, insulated with a mica envelope and the whole inclosed with a sheet steel casing applied under hydraulic pressure of two tons

per square inch. At each end of the heater the steel casing is extended to form a mounting lug and has two holes punched in it for the fastening screws. The terminals are at one end of the heater and are protected with a substantial metal cover.

Fig. 3 shows the pattern plate removed to display the heaters mounted on the angles in the frame of the machine. In

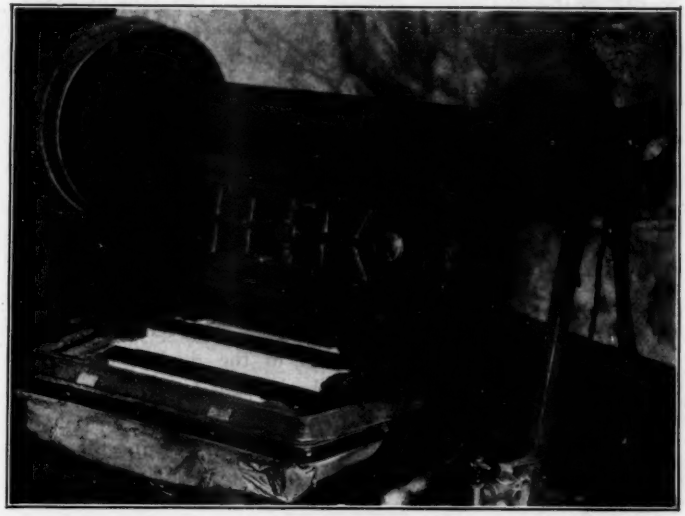

FIG. 3—STATIONARY MOLDING MACHINE SHOWING PATTERN PLATE REMOVED TO REVEAL POSITION OF STEELCLAD HEATERS

order to conserve the heat an asbestos heat insulating plate was placed just below the heaters to prevent loss of heat by radiation downward from the heaters.

Heaters Do Not Hinder Operation

The presence of the heaters did not in any way interfere with the usual operation of the machine or the functioning of the mechanical vibrator, and the entire installation was made without any modification of the machine other than the drilling and tapping of small holes for attaching the mounting angles.

The machine takes a pattern plate 16 x 11 x 2 inches. The two heaters applied were each 13 inches long 2 1/4 inch wide x 1/4 inch thick, and had a total rating of 300 watts at 110 volts. Connection to the source of power was made by means of a flexible cord and an ordinary separable attachment plug.

The simplicity, convenience and cleanliness of this method of heating metal patterns must be obvious. The cost of operation varies with different conditions, such as the size of the patterns, number of molds made per hour and the price paid for power. But the cost of operation is a relatively small item in any case and quite inconsiderable in comparison with the advantages of the method. As a matter of actual experience, in cases of which we have record, the electric method of heating patterns is really cheaper than the methods previously used.

It might be interesting to note that in the manufacture of fire brick and bathroom tiles, there is difficulty with the material sticking to the dies on the press plungers, just as the sand has a tendency to stick to the metal patterns. The remedy for this difficulty is the application of heat to the dies. Steam heat has been used but has many drawbacks, and lately electric heat has been successfully applied. The type of heater and the method of applying it is similar to that described for the metal patterns.

Discussion

CHAIRMAN CLAMER: As an advocate of everything electrical in the foundry, I have been very much interested in this paper as being just another practical application of electricity. It will not be many years before practically everything in our foundries will be electrically operated. It seems to be tending that way very rapidly, and instead of having the great difficulties that we foundrymen always have in the summertime in keeping our foundries going, on account of the hot disagreeable conditions prevailing I think that condition will be greatly overcome

and all those electrical appliances are certainly going to help us very greatly.

A MEMBER.—I would like to ask Mr. Cremer if a regulating thermostat can be attached to their heating device?

C. A. CREMER.—I do not think there is any reason why the thermostat could not be attached to this device, but with vibrator machines, I believe it might be a little difficult to secure the proper kind of thermostat to stand the vibration. I think with a little care we can do very nicely without a thermostat, though there are cases where the pattern might get extremely warm, and for that reason the thermostat might be advisable.

CHAIRMAN G. H. CLAMER.—Does there seem to be any tendency to the deterioration of the resistor if the heat is kept on indefinitely?

C. A. CREMER.—No, not at all; the temperature is only about 90 to 100 degrees so far as the patterns are concerned, and if the heater is placed properly, the entrance to the heater should not be above that temperature.

CHAIRMAN G. H. CLAMER.—The maximum temperature then is not high, it can be reached under any circumstances?

W. B. PERRY.—I would like to ask Mr. Cremer if he has experimented with different kinds of metal patterns?

C. A. CREMER.—I do not know whether any experiments have been made or not. The particular patterns I referred to were steel or iron patterns. I think the use of the heater is particularly advisable in the case of brass patterns, but I understand it works well with the others. If it is made for the metal of which the pattern is made, I do not think there will be any difficulty.

W. B. PERRY.—But aluminum transmits heat easily, so I think it would be particularly good for that.

A MEMBER.—How long have these insulated heating elements been in service on these plates?

C. A. CREMER.—About two years I believe.

A MEMBER.—How often would you have to replace the heating elements due to vibration and the disintegration of

your mica? That point used with the vibrating molding machine I think would give you something to study.

C. A. CREMER.—On the question of vibration, I do not really know; no failure has come to my attention. I think there is something to that; some of the vibrators might affect the mica after a time. I haven't any data available, but in the radiator machines, there is no vibrator, so far as I know, and we haven't had any cases of failure at all.

W. B. PERRY.—Can these heaters be obtained in an intricate form, or are they all straight and plain?

C. A. CREMER.—The heaters themselves are perfectly straight and the pattern is straight. There are some cases where the pattern was of an irregular shape, and hollow, and in that case, if you put a heater inside the pattern, instead of in contact with the plate, you let it heat by radiation, the pattern is merely a shell, the method of applying the heat is a question for each individual case.

R. R. SHIPMAN.—I have been asking a whole lot about this heating apparatus, electricity and gas, and I told the man from whom we bought our molding machines that we wanted to get rid of so much gas that blackens the patterns. He told me that benzine and bayberry wax was the remedy for patterns for molding machines. I have never used it for molding machine patterns, but I am going to try it. He said, "It will last half a day; put it on at noon time, and it will be all right the rest of the day; then put it on again at night and it is all right from morning until the next noon." Heating the pattern is a problem; it is a whole lot of work. Our work is very neat, close work, and the sand will stick to those brass patterns and sometimes you get them too hot. Another piece of work is in a hurry, the molder won't wait for it to cool, and he goes and gets a little hot sand, it is a little dry, and he puts the brass pattern into it and you get a dirty casting. I would like to hear from somebody that has had experience with that bayberry wax and benzine.

ALFRED NEAL.—I would like to corroborate the last speaker. I have used it with considerable success and am still using it. As far as heating the pattern is concerned, we have tried

that, but with no success. As he said, the time between using the pattern is such that it is either too hot or too cold, but the bayberry wax and benzine is the best thing yet.

A MEMBER.—I have been using bayberry wax and benzine, but I find that if you have a pattern screwed to a plate, if you are not very careful the benzine heats the wax off the joints. You have to be very careful in using it.

A MEMBER.—In regard to heating patterns electrically, we have been using electrical heaters for the last year and a half, and I know we had at least two of them in constant use every working day, and have no trouble whatever with them. They have been very satisfactory. Those are our own make. We bought some from a certain firm, which were not satisfactory. They did not last, but those we made seemed to be very good.

A Study of Insulated Core Oven Design and Performance

By C. F. Mayer, Cleveland

The question often arises, when core or mold drying ovens are discussed, as to what type of oven will perform its duties in meeting certain conditions most satisfactorily and most economically.

In order to meet these queries intelligently—and it would seem that intelligence is lacking not infrequently—considerable study and first hand observations are essential, the results of which are valuable only insofar as they represent fundamental principles rather than a host of data.

An exuberance of data of any sort tending to illuminate the design or operation of oven equipment, has always been conspicuously absent, although a comparatively small number of tests have been carried on. Most of these investigations seem to have been made with electric oven equipment. Great emphasis was always laid on the amount of material baked, and little stress given to the reasons for attaining the results.

The appearance of the electric oven, as a comparatively recent innovation to foundry and core room practice, has done a great deal to agitate investigation, and in consequence the more familiar oven equipments are also certain to receive due consideration.

It was our good fortune to have available, under actual working conditions, two electric ovens, of different manufacture and one oil fuel oven. Owing to their similarity in size and production requirements these ovens presented excellent material for investigation. The data and opinions offered, are taken from investigations covering a period of more than a year, and, as an educational effort in the line of thought presented it is hoped that sufficient interest will be aroused to continue the study for improved conditions.

Theory of Heating Capacity

We have been inclined to use a hit or miss theory in guessing oven capacity—either through ignorance or careless indifference. This is a most important and frequently costly source of error. Reverting to fundamentals, we are aware that during the process of heating the heat absorbed by the object is dependent on the weight W, specific heat C and temperature rise $(t_2—t_1)$, or formulatively,

$$Q=W\times C\times(t_2—t_1)$$

Likewise we know that the aggregate wall losses vary as the surface exposed A, the coefficient of heat transmission U and the temperature difference $(t_2—t_1)$, for a given time

$$K=A\times U\times(t_2—t_1)$$

The total heating capacity H_T of an oven, then, is the summation Σ of the heat absorption and transmission losses.

$$H_T=\Sigma\ (Q+K)$$

Where $Q=\Sigma$ of heat absorbed by objects heated

$K=\Sigma$ of heat losses (wall losses)

The quantity Q may be divided into four distinct groups, namely heating the material baked, heating the conveyance (or shelves), heating the air, and heating the walls and oven equipment.

The last item may be classed as initial or permanent absorption*. This heat is finally given up as radiation loss. The transmission losses, K, may be considered as the total losses through the walls and floor (other indeterminable leakages also must be included here).

It is essential that the various values governing the preceding points be pretty closely approximated to arrive at correct results in estimating heating capacity.

The results could be made exceedingly close in experimental work where test boxes are used. Our condition, however, differs materially in that we had widely varying conditions and application to actual practice. The necessity of the fundamental theory will be clearly illustrated.

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*Permanent absorption refers here to heat absorbed and maintained until discontinuation of the day's test.

Description of Apparatus

Figs. 1, 2 and 3 illustrate the general arrangement of various ovens and testing equipment. The illustrations give a clear conception of the oven installation, and of the other important features.

Oven *A* was constructed of light sheet metal walls separated by two inches of asbestos insulation. The size is indicated in Fig. 1.

An exhaust fan was connected to flues, extending down the

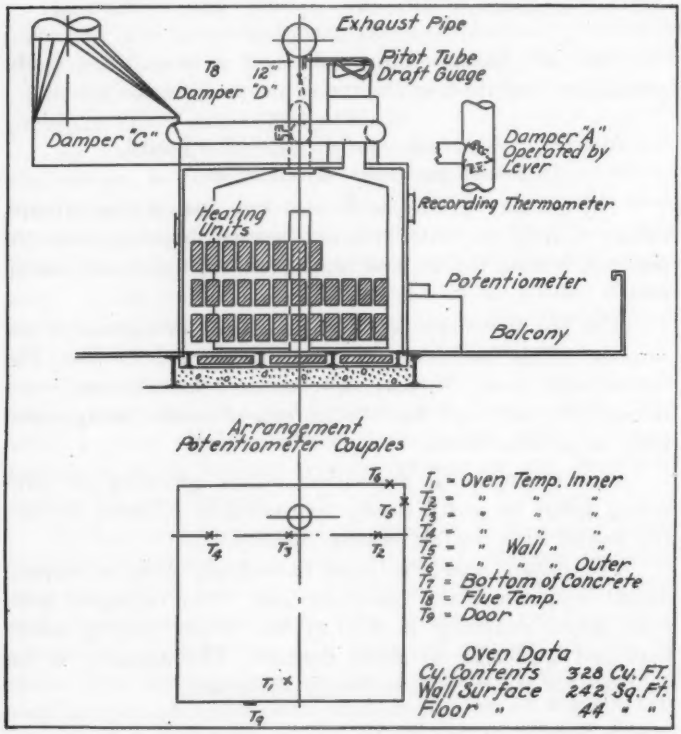


FIG. 1—ARRANGEMENT OF OVEN "A," EMPLOYING ELECTRIC HEAT

sides of the oven. The construction was such as to allow the return air to pass over the floor heating units. Dampers were provided for at *A*, *C* and *D*. Damper *A* acted as a by-pass so that the air could either be exhausted or recirculated. Damper *C* controlled a fresh air inlet. Damper *D* functioned merely as a secondary damper. Damper *A* was operated by means of a series of levers and a rod at the oven front. By means of

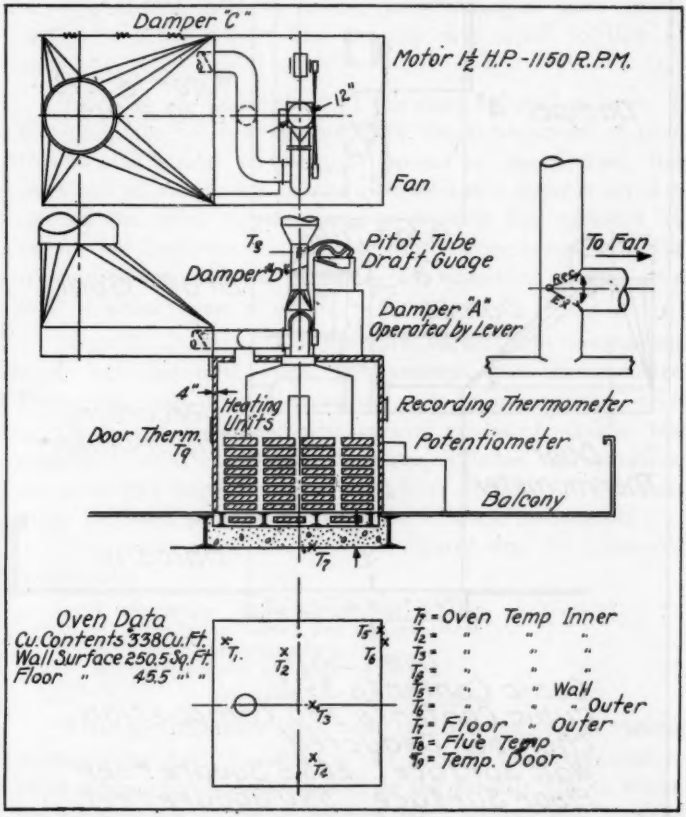


FIG. 2—ARRANGEMENT OF OVEN "B," EMPLOYING ELECTRIC HEAT

various notches, used as indicators for varying damper openings, the flow of air was fairly well controlled as desired. The hood functioned to remove such gases as might escape around the doors.

The heating equipment was of approximately 94-kilowatt capacity, with the units arranged as in the sketch, Fig. 1. The

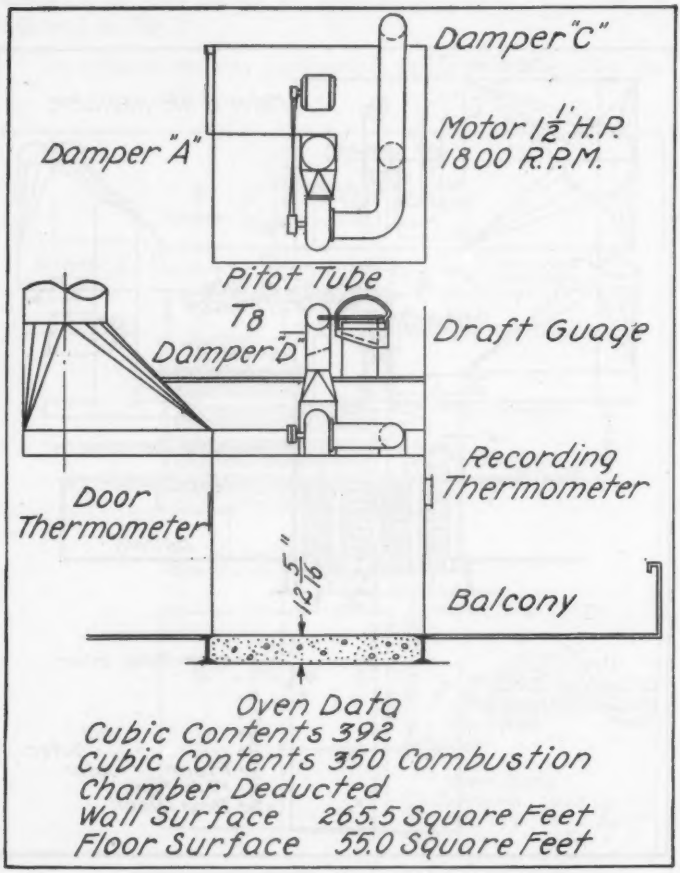


FIG. 3—ARRANGEMENT OF OVEN "C," USING OIL FUEL

control consisted of one 100-kilowatt automatic control panel operated in conjunction with a thermostat and relay, 440-volt, 3-phase, 60-cycle current being used. The floors were constructed of I-beams and concrete (mezzanine floor) as indicated in Fig. 1.

Oven *B* was constructed of light sheet metal walls, separated by four inches of block, consisting of diatomaceous earth. In general the other arrangements were similar to those in oven *A*. The heating units, however, were arranged more evenly and with better effect. The capacity was equal to that of oven *A*.

Oven *C* was constructed of the same material as oven *A*. Excepting for the heating equipment the arrangement of oven *C* was also similar to oven *A*. Instead of electric heat, this oven was provided with a firebrick combustion chamber on each side of the oven, together with a 3/4-inch high-pressure oil burner for each chamber. Owing to the space occupied by the combustion chamber the oven size was somewhat greater than that of either oven *A* or *B*.

Figs. 1, 2 and 3 illustrate the various test instruments used, including pitot tubes, thermometers and potentiometer. During the tests other instruments, such as anemometers, orsat apparatus, etc., were used with varying grades of success. The equipment used to greatest advantage included thermometers, oil measuring equipment and watt-hour meters. The results given are based principally on the use of these instruments.

The points most carefully investigated may be numbered as follows:

1. Radiation losses (including leakage ventilation)
2. Ventilation losses and observations.
3. Heating requirements.
4. Comparative qualities of ovens.

Absorption and Radiation

*The potentiometer leads were carefully located at various points in the oven to obtain a fair average inner temperature value. One lead also was located in the exhaust flue to obtain the temperature of the exhausting air. A lead was fastened

*These readings are not indicated in this paper.

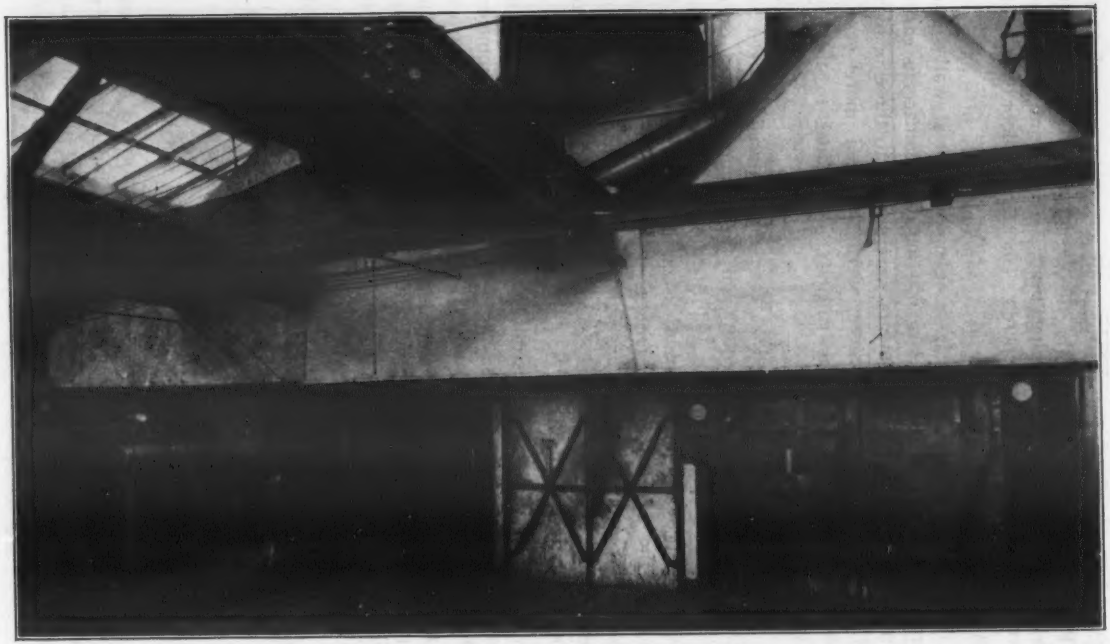


FIG. 4—FROM LEFT TO RIGHT ARE SHOWN THE OIL BURNING EQUIPMENT, OVEN "C," OVEN "A," CONTROL PANEL, AND OVEN "B"

as closely as possible to the inner metal surface, precaution in the form of a thin sheet of mica being taken to prevent short circuiting the potentiometer leads. Directly under the oven and fastened to the concrete a similar arrangement was made.

With the exception of the necessary internal oven equip-

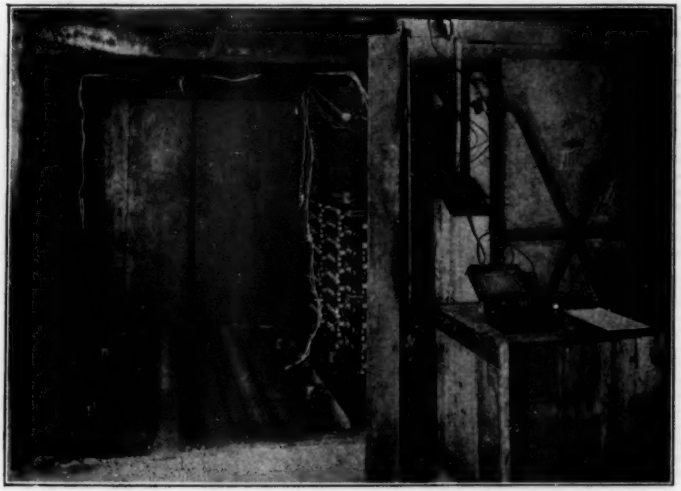


FIG. 5—ARRANGEMENT OF THERMOCOUPLES

ment the oven was tested with no load inside.

The temperature was allowed to build up to the desired degree to be maintained, and the thermostat was then adjusted to maintain an average temperature as required. Some little time elapses before complete absorption takes place and the oven reaches equilibrium, as is evidenced by the curves, Figs. 7 and 8.

Since the determination of the radiation losses is influenced by any possible heat loss through air leakage, every probable source of leakage must be sought out and eliminated within practicable limits.

For some time, the records were noted in tabular form. After the work seemed to be progressing favorably it was de-

cided to discard the tabular forms and the data was directly transformed into curves. This procedure allowed for excellent comparison of two ovens in simultaneous operation, as well as to indicate graphically the occurrences as the tests advanced.

By carefully examining Figs. 7 and 8, each successive step may be traced. The current was started at a convenient time with the oven at room temperature (averaging about 65 de-

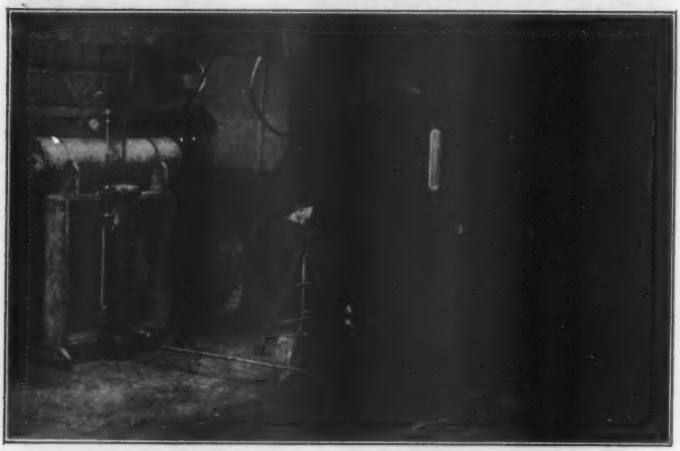


FIG. 6—OIL MEASURING EQUIPMENT AND OIL FIRED OVEN

grees Fahr.). In each case the uniformity of temperature rise is conspicuous and the time interval between the final temperature of 400 degrees (angle type thermometer) and the initial oven temperature, 65 degrees proved always to be nearly the same.

The average time consumed was 26.7 minutes for oven *A* with a two inch wall; the average power consumption amounted to 45.7 kilowatts.

On the other hand oven *B* with a 4-inch wall required an average time of 28 minutes and an average power consumption of 47.9 kilowatts.

These comparative results are interesting, since the facts are so consistent, and indicates that the thicker walls absorbed a

greater amount of heat initially than the lighter walled oven.

Continued inspection after the 400-degree temperature was reached showed that with all dampers closed, fan off, considerable power and time were consumed before the point of equilibrium was approached.

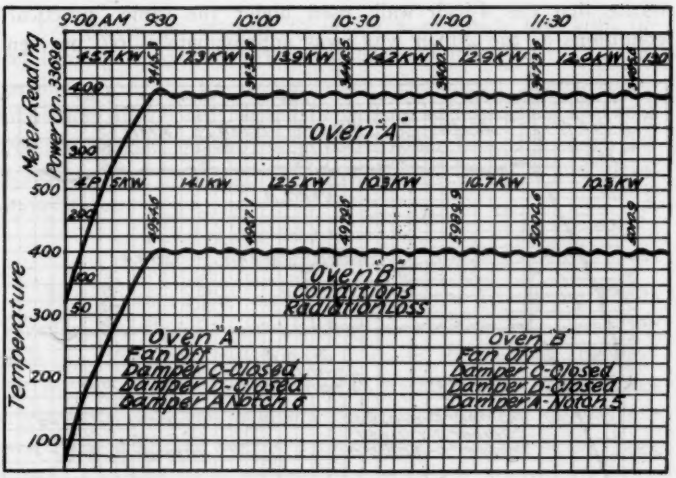


FIG. 7—CURVES SHOWING RADIATION LOSSES, OVENS "A" AND "B"

Referring to Fig. 7, oven *A* in the second 31 minutes consumed 17.3 kilowatts, in the third 30 minutes only 13.9 kilowatts and so on until 12.9 kilowatts was reached. The correct average loss was about 12.6 kilowatts radiation loss in 30 minutes or 25.2 kilowatts per hour.

The power consumption for oven *B* took a decided drop after the 400-degree temperature was reached, indicating over the second 30 minutes a smaller loss than occurred over the corresponding interval for oven *B*. This fact would indicate in the case of the thicker wall that the rapidity, with which the absorption reached equilibrium, was greater than that of the 2-inch, which together with the lower radiation rate, resulted

in a smaller current consumption. The radiation loss for the 4-inch wall averaged 21 kilowatts per hour.

Thus the transmission efficiency of the 4-inch wall and the 2-inch wall compare in the relation of $\frac{21.0}{25.2}$. This would indicate that the 4-inch wall, used under the same "practical" conditions as the 2-inch wall, was approximately 16.6 per cent

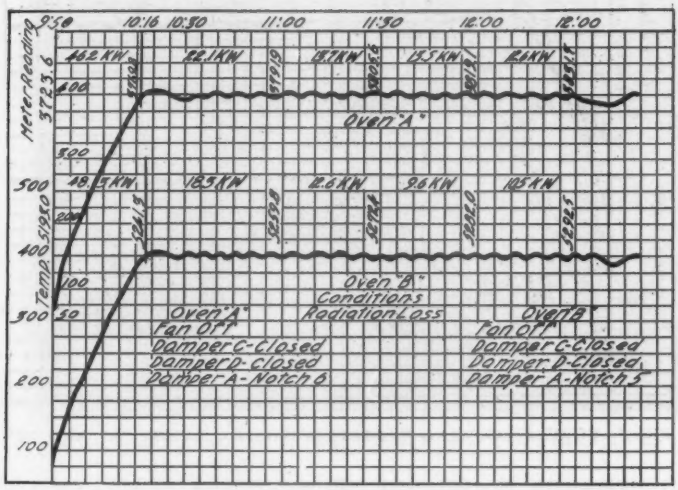


FIG. 8—CURVES SHOWING RADIATION LOSSES, OVENS "A" AND "B"

more efficient. Fig. 18 illustrates the difference between an ideal insulation test as the writer found it and that obtained in actual practice. There is ample evidence that it would be difficult to obtain the ideal results in practice.

Radiation Losses Oil Oven

The results obtained in regard to uniformity of temperatures, once the desired temperature was arrived at, were good. It was particularly noted, however, with ovens of the size tested that difficulty is encountered if temperatures less than 430 degrees Fahr. are adopted as the best temperatures.

According to Fig. 9 about 53 minutes are required to reach 450 degrees Fahr. By comparing Figs. 9 and 10, however, it will be noted that the initial heating is variable. This is readily comprehended due to the fact that the burner operation fluctuates constantly during initial heating and no two similar results are likely to occur.

Of course, an attempt to obtain a radiation loss with direct heating equipment, where actual combustion occurs, is impossible, owing to the necessity of ventilation. Similarly recirculation of the heat would be impractical owing to the back pressure exerted on the oil burners. Therefore, the losses indicated by the curves are a summation of the wall and ventilation losses.

Ventilation

The accompanying tables disclose some interesting points regarding the losses corresponding to variation in ventilating capacity. Particular mention is made in the case of the electric ovens *A* and *B*; after every precaution has been taken to eliminate leaks, all dampers closed and the fan off—as expected the kilowatt loss is a minimum, as indicated in Figs. 7, 8, 11.

It often is presumed that by recirculation, heat is converted, whereas from inspection, it is observed that with the fan on and main damper in notch No. 6 (recirculating) in the case of the oven *A* a difference of 33.4 and 25.2, or 8.2 kilowatts is lost in addition to the radiation loss. This figure is extremely high as compared with that for oven *B*, and would indicate that there was a source of heat loss through leakage which was not remedied in this case. If it were practically possible to avoid all usual sources of leakage no appreciable saving in heat would be possible by recirculation. Where leakages are presented a fan merely is transformed into a blower and the tendency of stirring up the air is to move the warm air to colder regions. The most valuable tendency in this regard would be toward uniformity of heat.

Table I
HEAT LOSSES

Condition	Notch	K.W. loss per hour	B.t.u. a sq. ft. per hour	Gal. oil per hour	Temp. at door	Velocity pressure inches water
			Oven A			
Fan off.....	6 r	25.2	300	....	400	0
Fan on.....	6 r	33.4	399	....	400	0
Fan off.....	6 r	28.2	336	....	440	0
Fan on.....	6 r	42.4	507	....	440	0
			Oven B			
Fan off.....	5 r	21.0	242	....	400	0
Fan on.....	5 r	22.0	254	....	400	0
Fan on.....	1 ex	27.4	316	....	400	.05
Fan off.....	5 r	21.6	249	....	440	0
Fan on.....	5 r	28.4	327	....	440	0
			Oven C			
Fan off.....	6 ex	39.7*	423	.94	430	0
Fan on.....	1 r	71.2	756	1.72	430	0
Fan on.....	6 ex	97.0	1030	2.30	450	.04

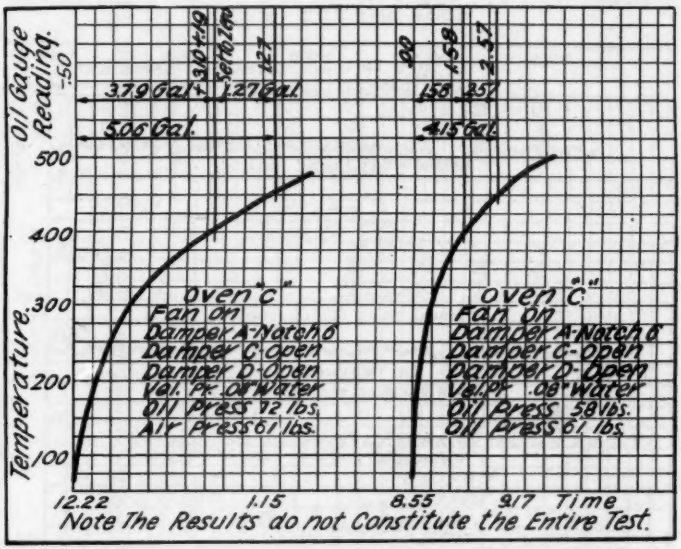
Note:—6r, 5r and 1r indicate dampers in maximum recirculation position and with fan off represent minimum ventilation. 6ex and 1ex where mentioned are indications of wide open exhaust dampers. *Equivalent kilowatt consumption.

Similar trials were made with the oil burning oven, showing in Figs. 12, 13 and Table I. These trials indicated that a natural draft condition proved most economical in fuel consumption. The amount of air passing through the vent pipes was too small to be recorded. It will be noted that the recirculation method allowed an appreciable amount of air flow and resulted in a rather great fuel consumption as compared with the natural draft result. The temperature maintained in the case of the oil burning oven was approximately 430 degrees Fahr.

Attention is called to the resulting fuel consumption conditions of ovens *A*, *B* and *C* when the minimum amounts of ventilation are prevailing at approximately 440 degrees.

	Equivalent K. W. Loss per Hr.	Temp.	Gallons Oil per Hr.	B.t.u. Loss per sq. ft. per Hr.
Oven A (Fig. 11)				
1. Fan off 6 recirculating	28.2	440		336
2. Fan on 6 recirculating	42.4	440		507
Oven B (Fig. 11)				
1. Fan off 5 r.	21.6	440		249
2. Fan on 5 r.	28.4	440		327
Oven C (Figs. 12 and 13)				
1. Fan off 6 ex.	39.7	430	.94	423
2. Fan on 1 r.	71.2	430	1.72	756

For all practical purposes, other conditions remaining the same, a temperature difference of 10 degrees Fahr. would not necessarily result in a great variation in fuel consumption, so if we may compare the results approximately on a percentage basis, it is seen that the oil oven, compared with the electric



FIGS. 9 AND 10—TEMPERATURE—TIME DIAGRAM OF OVEN "C"

oven with 4-inch wall as 100 per cent efficient, had a corresponding efficiency of 54 per cent. The electric oven with a 2-inch wall in this sense was 77 per cent efficient. These values are applicable with ventilation at a minimum for the electric ovens.

The preceding efficiencies compare as follows:

	With ventilation Per cent	Minimum ventilation Per cent	Difference Per cent
Oven A =	50	77	27
Oven B =	77	100	23
Oven C =	30	54	24

Table II

BAKING RESULTS

Oven A

Bake number	Length of bake, minutes	K.W. power on, minutes	K.W. power used during bake	Fan on, minutes	Temperature, rack in	Temperature, rack out	Temperature, fan on	Temperature, fan off	Total pounds cores	Number of cores	Total pounds iron	Pounds cores per K.W.	Total weight per K.W.	Pounds cores per gallon	Cost per 1000 pounds cores
12	82	39	68.8	10	400	375	400	425	382	....	1759	5.5	31.1	....	$5.46
13	80	37	65.9	11	400	...	400	425	358	1438	1989	5.4	35.6	....	5.56
14	77	37.5	66.6	9.5	400	...	400	425	324	1768	2072	4.9	35.9	....	6.12
							Oven B								
21	75	37	59.1	Off	400	370	400	425	304	1280	2084	5.2	40.4	....	5.77
22	69	37	57.9	10	400	380	400	425	244	1277	2023	4.2	39.1	....	7.15
27	74	34	60.0	9	400	...	400	425	298	....	2014	5.0	38.5	....	5.99
							Oven C								
29	80	31	2.621	28	350	400	350	455	297	288	2374	2.6*	....	113.0	.71
30	91	38	3.0	35	400	...	310	450	373	....	1996	2.87	....	113.3	.64
31	73	38	2.97	38	410	...	410	450	217	....	2164	1.7	....	73.0	1.10

Note: *Pound per kilowatt (Equivalent). Assumption: 18,500 B.t.u. per pound oil; 3,412 B.t.u. per kilowatt; and 8 pounds per gallon.

In the cases illustrated the small increase in ventilation apparently decreased the heat efficiency about 25 per cent; consequently it is exceedingly important to choose an amount of ventilation not in excess of the requirements.

In the case of the oil oven it was found that the recirculation principle is impractical due to difficulty with the burners and smoking and it was probably due to the fact that a small amount

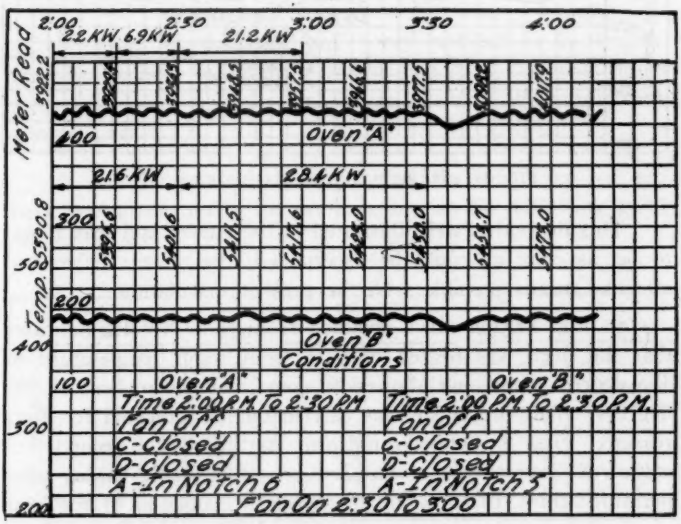


FIG. 11—FUEL CONSUMPTION OF OVENS "A" AND "B"

of ventilation was present that the attempt was successful to a certain degree.

Baking

Figs. 14, 15, 16 and 17 represent a number of typical bakes produced by the electric and oil ovens. A final summation of the bakes are recorded in Table II.

Our effort in obtaining the best representative bake in each instance was reduced, after some experimentation, to allowing the attendant to apply his own judgment, to a large extent gained from comparatively long contact with the ovens.

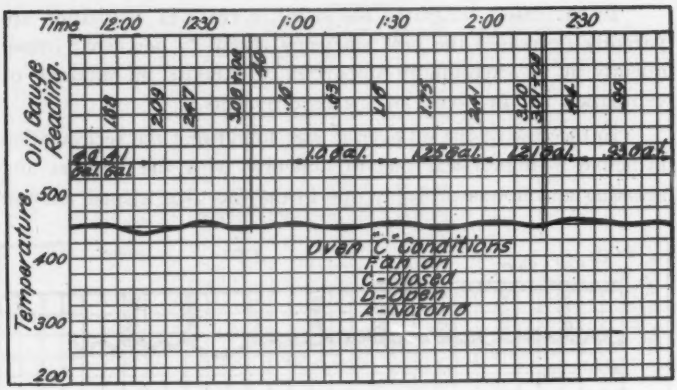


FIG. 12—OPERATING DATA ON OVEN "C"

This method is well illustrated in the curves and was found to be, as close as could be ascertained, the most reliable and effective means possible with the present installation.

In Fig. 14, the curve obtained from bake No. 12, indicates that the oven was heated initially from room temperature to 475 degrees Fahr. and allowed to come to uniform heat at 400 degrees. This procedure was carried out as indicated for four reasons: First to obtain a uniform starting basis; second, because 400 degrees was assumed the most desirable baking temperature; third, to allow an intelligent investigation of the heat required for baking purposes; and fourth, due to delay in racks being loaded with cores.

A rack of cores was loaded in at 400 degrees, (Fig. 14), consuming a varying amount of time from 25 to 60 seconds to move in, remove the elevating truck and shut the doors. A resulting temperature drop occurred in each instance of approximately 80 degrees, the drop terminating in the neighborhood of 320 degrees. This drop was overcome in about 25 minutes of power application. During this period the ventilation condition was assumed the same as for determining the radiation losses, namely, fan off, dampers closed. At the point where 400 degrees was again reached a pungent baking odor

was noticeable, indicating that the baking process was well under way. The fan was started at this point. When a temperature of 425 degrees was reached, both the fan and power were shut off and the temperature again descended gradually, as the process of absorption and radiation continued. Several inspections of the cores during the final soaking period determined the time for removal of the cores. These inspections affected the temperature only slightly.

Removal of the rack and cores resulted in a temperature drop similar in nature to the loading drop, the most prominent difference being the rapidity in reaching the normal temperature again.

It will be particularly noted that the condition for each bake was made nearly the same insofar as the following points are concerned:

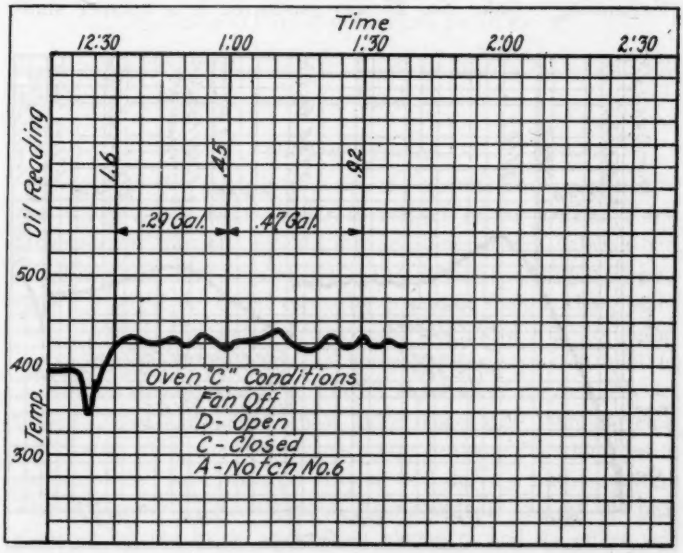


FIG. 13—ADDITIONAL DATA ON OVEN "C"

1. Loading temperature
2. Removal temperature
3. Time for discontinuing fan and power service.

Consequently the true amount of power for each bake could be closely ascertained.

Relative to the preceding paragraphs, it must be kept in mind that temperature drops and power requirements depend entirely on the nature and size of the load, a variation of which will produce similar variations in time for temperature recovery and power consumption. The consistency of the results in cases illustrated here, indicate that the total loadings were quite uniform for most cases and in conformance with this foundry's standard practice.

Bakes 21, 22 (Fig. 16) and 27, using the electric oven with a 4-inch wall, were conducted in a manner similar to the preceding ones, with a possible exception. Bakes 21 and 22 were conducted with the fan on and damper *A* set for notch No. 1 (Exhausting). Bake No. 27 was conducted in a manner simi-

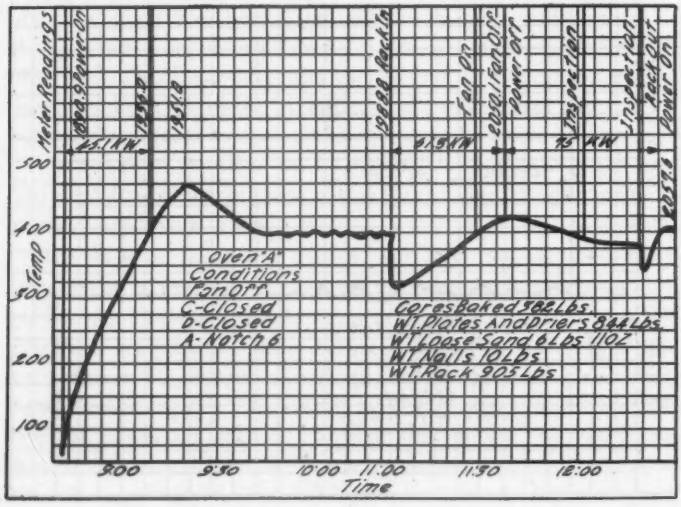


FIG. 14—RESULTS OF A TEST ON COREBAKING IN OVEN "A"

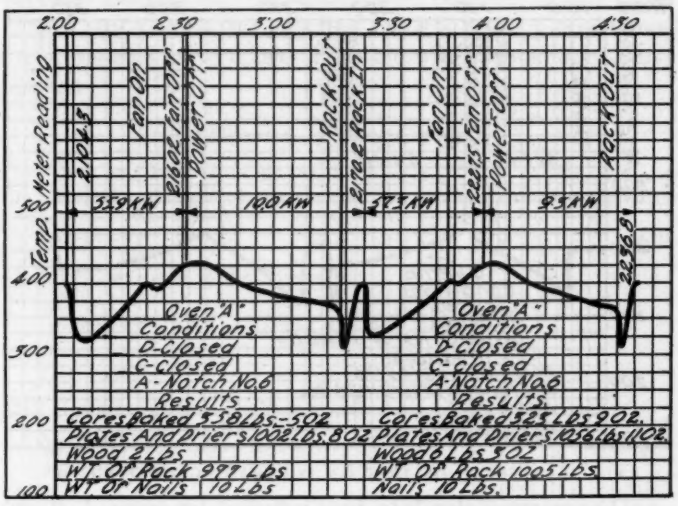


FIG. 15—DATA ON COREBAKING IN OVEN "A"

lar to bakes 12, 13 and 14. The curves possess the same characteristics as those of preceding bakes.

Oil Oven Bakes

As with the preceding ovens the general characteristics of the baking ovens were similar in respect to the electric ovens. However, at various periods during some of the bakes, some difficulty was experienced with the burner operation, which caused a slight deviation from the generally smooth characteristics. Table II illustrates three typical bakes and Fig. 18, showing bake No. 29, conveys the nature of progress. It will be noted that the tendency for the oil oven, after the burners are turned off, is to retain its heat more tenaciously than the electric ovens. The curve continues quite horizontally to the completion of the bake with no drop to 400 degrees until removed. This difference in characteristic is undoubtedly due to the heat absorbed by the brick combustion chambers and its effect was consistent for each bake.

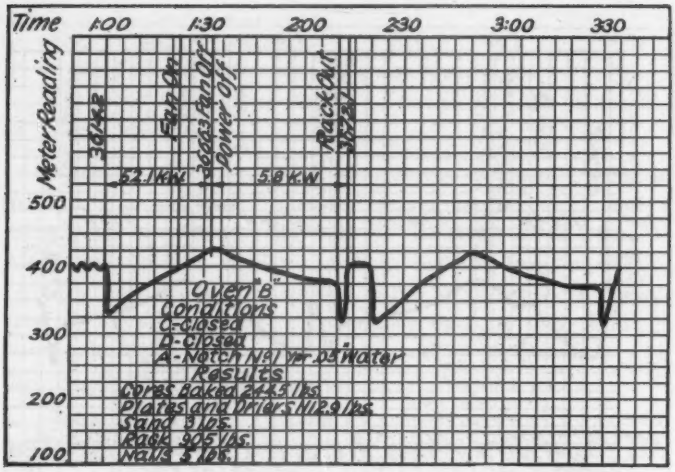


FIG. 16—RESULTS OF TEST ON COREBAKING IN OVEN "B"

The average bakes have been indicated for ovens *A*, *B* and *C* for comparison. The oil consumption for oven *C* also is put in equivalent form as kilowatt consumption.

Of particular interest is the time required for baking purposes, relative to cores of the type mentioned, Table III. The data clearly shows that the time of bake, the power consumption and weight of material are directly dependent on one another. An increase or decrease in length of bake is due to an increase or decrease in weight of material or heat, and a like increase or decrease in power or fuel consumption follows. With operating conditions remaining a constant these facts are of great importance in the calculation of proper heating equipment.

It is peculiar but entirely plausible that although oven *B* proved to be the more efficient from a radiation standpoint, it actually baked less pounds of cores per kilowatt than oven *A* with a 2-inch wall.

Much has been said about actual electric corebaking capacity being in the neighborhood of 12 pounds per kilowatt, yet we find actually in this case it was 5 pounds per kilowatt. If the various construction features in and about the oven are

carefully analyzed and the figures noted elsewhere in this paper studied, the reasons are apparent for this result. Several concrete examples serve admirably to illustrate the sources of dissipation.

Distribution of Heat Consumed

Oven *A*, Bake 12 (Fig. 14)

(1) Radiation losses (400 degrees door temperature assumed) kilowatts

$$K=25.2\times\frac{82}{60}=$$ 34.50

(2) Heating Racks, plates, driers, etc.

$$Q=\frac{S\times W\times(T_1\times T_2)}{3412}=\frac{.115\times1759\times\left(\frac{400+375}{2}-65\right)}{3412}=19.15$$

(3) Heating Air (Fan on 10 minutes)

$$Q=(33.4-25.2)\times\frac{10}{60}=$$ 1.37

Power loss — 55.02
Total power used — 68.8

Useful power to bake cores 13.78

It is assumed that the final temperature of the entire mass is an average of the initial and final baking temperatures.

Oven *B*, Bake 22 (Fig. 16)

(1) Radiation losses (400 degrees door temperature assumed) kilowatts

$$K=21.0\times\frac{69}{60}=$$ 24.20

(2) Heating Racks, plates, driers, etc.

$$Q=\frac{S\times W\times(T_1-T_2)}{3412}=\frac{.115\times2023\times\left(\frac{400+380}{2}-65\right)}{3412}=22.10$$

(3) Heating air (Fan on 10 minutes)

$$Q=(27.4-21.0)\times\frac{10}{60}=$$ 1.06

Power loss — 47.36
Power used — 57.90

Useful power to bake cores — 10.54

In the first illustration of the distribution of power we find

Table III

CORE DESCRIPTION

Description of core	Sand type	Core weight ounces
1½-inch, No. 3 check body	C	17.2
⅜-inch J. D. side angle body	B	2.04
¼-inch No. 2 globe body	Special	0.64
2-inch special J. D. globe C. piece	C	7.21
2-inch std. J. D. globe C piece	C	11.29
1¼-inch std. J. D. globe C. piece	C	1.93
2-inch std. J. D. globe C. piece	C	3.56
Feeder clamp	A	1.14
1¼-inch J. D. std. globe C. piece	C	5.42
2-inch J. D. std. globe body	C	27.08
1¼-inch special gate bodies	B	7.0
¾-inch J. D. std. angle body	C	1.27
Type C trolley splicer	A	2.90
Special Clark splicer	A	3.46
Clark splicer	A	3.03
Type D splicer	B	4.4
½-inch, No. 2 vertical check body	C	2.48
1-inch special gate body	B	4.38
2-inch J. D. std. globe body	C	...
2-inch J. D. special globe body	B	30.0
2-inch J. D. special globe body	B	42.5
Trolley wheel		16.5

A—Sand = 60 parts by volume.
40 parts sand blast dust.
3 parts linseed oil.

B—Sand = 80 parts sand.
20 parts sand blast dust.
3 parts linseed oil.

C—Sand = 50 parts sand.
10 parts crushed cores.
40 parts molding sand.
3 parts linseed oil.
5 parts glutrin.

that 50 per cent of the total power used was lost in radiation; 27.8 per cent lost in heating the racks, plates and driers; and 2 per cent in ventilation. Only 20.2 per cent of the power consumed actually was useful. The oven efficiency might be stated as: $\frac{\text{Useful input } 13.78}{\text{Total input } 68.8} =$ or 20.2 per cent.

Similarly for oven *B* 41.7 per cent of the total power used was lost in radiation, 38.2 per cent was lost in heating the racks, plates and driers; and 1.80 per cent in ventilation. Only 18.3 per cent of the power used actually was useful. The oven in this case would be 18.3 per cent efficient.

Fuel Cost

A brief comparison of the average fuel cost per thousand pounds of cores is made in Table II, assuming a price for oil as 8 cents a gallon and power as 3 cents per kilowatt.

Cost Per Thousand Pounds of Cores

Oven *A* (Electric)	Oven *B* (Electric)	Oven *C* (Oil)
$5.76	$6.39	$.815

These relative values vary with fluctuations in fuel prices but may, nevertheless, be assumed as a general indication of their comparative status.

The more important conclusions drawn from the preceding observations may be summed up as follows:

As indicated by the formulas and examples, a basis for determination of the heating requirements is available. Scientific rather than hit or miss measures should be adopted in oven designs, although the available data is somewhat meager and perhaps imperfect at present.

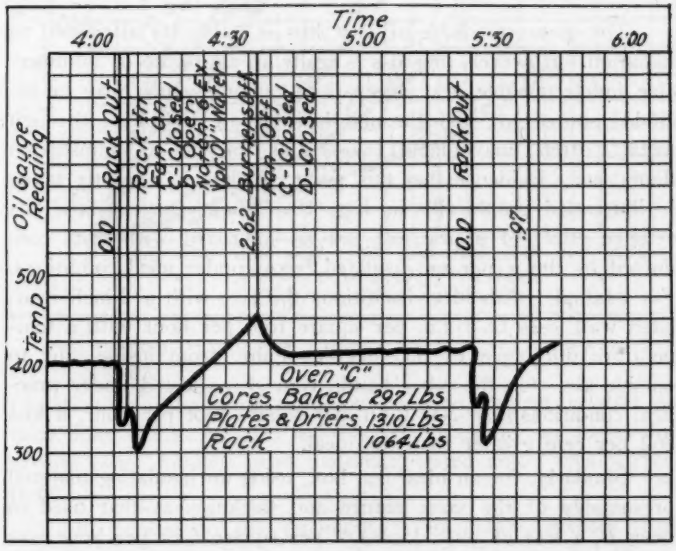


FIG. 17—RESULTS OF TEST ON COREBAKING IN OVEN "C"

The formula "H_t"$=\Sigma(Q+K)$, forms a basis for heat calculation.

Ventilation, in core baking, serves three ends:

1. In a baking capacity (to furnish oxygen)
2. For combustion (oxygen)
3. For ventilation (to remove fumes and moisture)

Usually the first item receives its requirements if the last item is fulfilled. The second item is necessary for ovens using fuels other than electricity. From the results observed it is quite evident that minimum ventilation, or just a sufficient amount to fulfill the requirements, is desirable, and excesses should be guarded against. The problem of ventilation lies probably in the difficulty in obtaining the correct amount. This is quite easily solved by furnishing a sufficient quantity, determined principally from past experience, and, by a judicious use of dampers. The effects of minimum and greater than minimum ventilation have been illustrated as decidedly favorable to a minimum quantity.

The greatest source of heat loss is indirectly attributed to radiation. However, this loss is really an aggregate of innumerable indeterminable heat dissipations, among which may be included sources of loss through lack of air tightness, through metal (often unavoidable), losses at the doors, uninsulated floors, etc. Evidence that this point of view is correctly taken is illustrated graphically in Fig. 18. These curves show the relative effect of a practical test as compared with tests conducted by the writer on insulated boxes under ideal conditions. For example, with ideal conditions the box with a 2-inch insulated wall loses 65 B.t.u. per square foot per hour with a temperature difference of 335 degrees Fahr. from inside air to outside air. On the other hand, oven *A*, as tested under practical conditions, lost 300 B.t.u. per square foot per hour, a loss 362 per cent greater than the ideal.

Similarly, for an ideal test box, using an insulating material presumably of the same nature and thickness as that used in oven *B*, a loss of only 35 B.t.u. per square foot per hour was observed. The transmission loss for oven *B*, was in the neigh-

borhood of 234 B.t.u. per square foot per hour, 570 per cent greater than the ideal condition. The theory advanced regarding the reasons for the degree of separation of the practical and the ideal conditions is further strengthened by the trend of the two sets of curves. Note that the curves for the practical

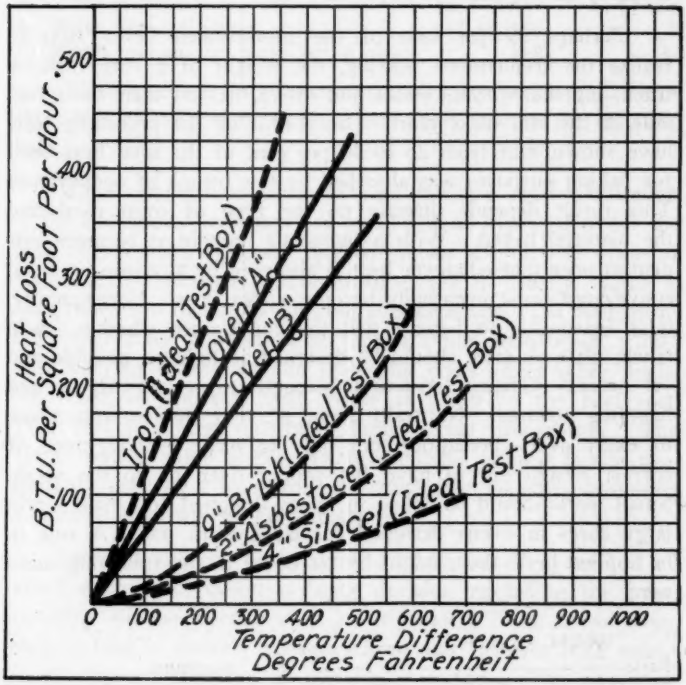


FIG. 18—COMPARISON OF IDEAL AND ACTUAL INSULATION

condition and the ideal condition have an evident relation to each other. Fig. 18 also indicates the transmission losses for several other familiar oven materials, tested under ideal conditions.

An increase in the thickness of insulation, greater than 4 inches might possibly increase the general efficiency, but this is

questionable inasmuch as an efficiency increase after a 4-inch insulation is reached, becomes comparatively small and the cost relatively great. Emphasis is more essential on care in eliminating avoidable losses. Good conductors of heat should never be sanctioned for oven flooring or combustion chambers if economy in operation is a primary desire.

Perhaps 99 per cent of the foundrymen never stop to realize the tremendous bearing, the weight of a core rack or truck, together with the plates and driers, has on their oven fuel bills at the end of a year. The results of the preceding tests have shown that from 25 to 40 per cent of the total heat used for baking purposes was absorbed by this means of conveyance. This result depends directly on the type of oven used and the material baked. With a moment's thought it becomes evident at once that whatever heat is absorbed by any iron or metal conveyance must eventually become a total loss. Consequently, it is reasonable to believe that the conveyance whether, rack, truck, plate or drier should be designed as light as possible and yet possess sufficient structural strength to resist warping and handling stresses. Naturally then, it is of utmost importance to exert every precaution not only to have a conveyance of correct design but to have the proper oven to do the work. Small work should be baked in ovens designed for small work, large cores in ovens designed for large work, etc. A rule to be applied here, then, might be set down in the following manner.

$$\text{Ratio} \frac{\text{Weight of cores}}{\text{Weight of metal or other conveyance}} = \text{maximum}$$

In other words the ratio of cores to be baked to the weight of shelves, racks, trucks, driers and plates should be balanced so as to obtain a maximum bake of cores for a minimum weight of conveyance. The result will be further effected by the length of bake. The longer the bake the less will be the loss of heat due to the removal of the nondesirable metal.

In connection with the preceding it might be interesting,

to refer to a recent test made with electric ovens, at the plant of the Muncie Foundry Co.

	Muncie Test	Test Oven *A*
1. Weight of cores per bake pounds	1300 to 2900	324-382
2. Weight of truck pounds	1500	2000
3. Time of bake	3 to 7 hours	77 to 82 min.
4. Ratio Cores to Iron	.85 to 1.95	.19
5. Result, pounds of cores per kilowatt	10.8	5.5

The preceding comparative examples are given to illustrate the effect of the weight of iron, cores and time on the resulting bake.

All losses reduce efficiency and increase cost. However, if the conditions presented are equal for all types of ovens the cost of operation becomes directly dependent on the price of fuel and maintenance. Maintainence cost is usually vague in comprehension owing to entering complications. Oil fuel burning requires the application of pumps, tanks, motors, etc.; likewise varying conditions and operating costs affect other fuels. The cost, or apparent cost, really is based on the fuel cost. This cost has been illustrated from actual observation. The B.t.u. heating value of the various mediums of heat is also customarily used as a basis for estimating heating costs, assuming a relative efficiency in each instance.

Lack of data on costs covering operation of ovens and all allied equipment, makes a hasty decision regarding the practicability of the electric oven an injustice. From observation, electric heat is entirely reliable, clean, and requires little attention. Its performance is pleasingly uniform. The operating costs are definite, undoubtedly the cost is its only important offense. From all present indications the possibilities of the electric oven depend principally on local fuel prices or the speculative nature of the foundryman.

The writer wishes to acknowledge with thanks the cooperation and assistance of F. Wolfe and A. A. Grubb of The Ohio Brass Co., Mansfield, O., in collecting material for the subject presented.

A Managerial Study of Oxyacetylene Cutting and Welding in Foundries

By G. O. Carter, New York

While the oxyacetylene industry owes its development largely to the energy and efforts of sales engineers who have studiously sought out uses and users for the process, the industry is equally indebted to its farsighted policy in carrying on research and application engineering to establish definite knowledge of the process—its limitations, as well as its possibilities. Indeed, one may say that, if the sales engineer was the chief agency in putting the oxyacetylene industry on its feet, research and application engineering are the forces that will hold the ground already gained and that will extend the process to realize its ultimate usefulness to man.

It is now several years since a few of the latter group of engineers began to make a close practical study of cutting and welding in foundries with a view to determining sound practices. Being unhampered by responsibility for the sale of apparatus or supplies, they devoted their attention to installations as a whole and to the establishment of correct methods in application of the welding and cutting processes.

Installation of Equipment

Oxyacetylene cutting is an important part of the manufacturing process in foundries, and it is always localized. For that reason the gases for the blowpipes can be supplied by means of pipe lines, and the foundry floor can be kept entirely clear of cylinders. This saves considerable handling of cylinders and is one of several operating economies that result from piping the gases.

When acetylene is piped to the cutting or welding station the generator should not be located immediately in the foundry but in a separate building, so situated with reference to the storage platform for oxygen that one man can attend to both of the gases. There must be an adequate supply of fresh water

for the generators and provision should be made for convenient disposal of the sludge. There are several reliable types of acetylene generators on the market, and in every locality are salesmen who will supply special information on request. The initial acetylene pipe line should take into account not only existing needs, but the possibility of future expansion. All-welded lines are giving very good satisfaction wherever they are in use. Their original tightness can be determined by the pressure and hammer test. Due to the character of construction, a line that has passed such a test satisfactorily should not require any outlay for upkeep or repair for many years.

Oxygen should be piped to the foundry from an oxygen storage and manifold room, so located that it will be easy to transfer cylinders from a railroad car or truck. Reserve oxygen cylinders should be stored on a platform level with the car or truck body, so that it will not be necessary to lift or lower the cylinders. If a level platform is used, the cylinders can be stored on end instead of being laid on their sides, as is the custom in many places.

Cylinders for immediate use should be rolled on end from the storage space to a small manifold room close by. As most foundries do considerable welding, as well as cutting, it is of advantage to use a low pressure pipe line to supply the oxygen to the welding station where the pressure need not exceed 30 pounds. This welding pipe line can therefore be brought to the manifold and combined with the cutting system in a manner to utilize a considerable part of the oxygen remaining in cylinders after the pressure has fallen below the working pressures demanded for cutting. This may be accomplished by means of a three-section manifold.

In operation, one section of the three-section manifold is supplying oxygen to the feed line for the cutting station at a pressure of approximately 150 pounds. Another section of the manifold, composed of cylinders, which had previously served the cutting station until they could no longer maintain a pressure of 150 pounds, is supplying the welding line. These cylinders would feed the pipe lines to the welding station at a

pressure of approximately 30 pounds. The third section permits the removal of empty cylinders which have been exhausted on high-pressure cutting and low-pressure welding lines and the substitution of filled cylinders which then stand by for high-pressure line service on the next shift. This section exists merely for the purpose of permitting the exchange of empty cylinders for full ones, so fresh cylinders will be immediately available and no time of cutting and welding operators will be lost.

In this combination high-class, large-capacity regulators are used between the outlets of the manifolds and pipe lines. These regulators, because each serves a separate line, do not require frequent adjustment. To avoid regulator difficulties that might result from cold weather, it has been found advisable to install a small steam coil near the regulators. In fact, it is desirable to keep the temperature of the manifold room well above the freezing point at all times.

It is customary to use 10 cylinder manifolds, as this insures a sufficient supply of gas for several hours, even in a busy foundry. This makes it possible for one man to attend to the oxygen manifolds and look after the acetylene generator, which ought to be of sufficient capacity to supply acetylene for an entire day from one charge of carbide.

The oxygen pipe lines should be welded lines, carefully cleaned of oil, then tested to 500 or 600 pounds pressure to make sure of tightness. The valve should be controlled by well-made station regulators, so pressure regulation will be thoroughly dependable. These regulators ought to operate for long periods without giving trouble, because they do not have to be taken off cylinders and put on cylinders constantly, as is necessary with regulators when individual cylinders are in use. One of the advantages of having a steam coil near the oxygen regulator is the fact that warm oxygen is appreciably more efficient than cold oxygen, especially on heavy cutting, and for this reason, the coil is sometimes supplemented by a steel jacket placed around the pipe near the regulator.

The blowpipe, of course, is an important part of the installation, for it is in this apparatus that the two gases are combined for the cutting operation. There are many different makes of blowpipes. Correct designs, good materials, and proper workmanship are the most important factors. Different blowpipes have different characteristics. One type, for example, may be designed for high efficiency, another type for special freedom from backfiring, and yet another may aim at minimum weight. Each user will determine for himself what characteristics he requires in the tool and he will judge the blowpipe accordingly.

Whenever a blowpipe is used it should be kept in good condition, so that gas passages are clear and the joints are leak proof. The proper tip should be used for the cutting work being done. Many operators have a tendency to use oversize tips, but this is not good practice owing to the unnecessary waste of the gases.

Holding Work for Cutting

For many kinds of cutting it seems advantageous to have the work lifted up, so that the risers will be on a level with the operator's hips. In such cases, cutting benches or frames should be provided to hold the castings. This might be called a part of the oxyacetylene installation because it is an important factor in the economical use of gases and in promoting clean cutting.

The welding station is an important part of the oxyacetylene installation, because there are many places where oxyacetylene welding can be used to advantage.

It is desirable to have preheating equipment and annealing bins at the welding station. If the castings in general are not composed of large units, the preheating should be performed in fixed furnaces, but either oil or gas burners should be provided for the preheating of large castings. Maintenance and repair welding and cutting can be used to great advantage in most foundries. For such purposes portable outfits, consisting of oxygen cylinder, oxygen regulator, acetylene cylinder and individual regulator should be used unless this work is to be done in close proximity to pipe lines. Such an outfit might well be

called an "emergency outfit" and it would probably be placed under entirely different administrative control than that having charge of riser cutting equipment. The major uses of the process in a foundry are in connection with production. Maintenance and repair welding and cutting more naturally come under the maintenance engineer or master mechanic.

Operation of Cutting Process

We must recognize that in many foundries it is impossible to attain ideal conditions for one process without some other parts of the work having to make sacrifices. It is well to keep in mind, therefore, that to put out a large tonnage at the expense of efficiency, or where there is some other warrant, the cost will be higher than under more favorable conditions which permit of economic practice in oxyacetylene cutting.

Probably the most important things connected with cutting are the character and condition of the risers. It is highly desirable that they should be sound and that the necks should be thoroughly clean. The soundness of a riser depends upon the molder and the steelmaker. Defects which show up at the neck of a riser are things which the foundry management is always fighting. The oxyacetylene cutter considers himself fortunate if he finds 75 per cent of the risers thoroughly sound. The necks of the risers can be cleaned either by scraping or by sandblasting. Where the risers are scraped the work should be done by a helper, as the operator's time is too valuable to expend on a purely preparatory operation.

Even a little sand interferes seriously with the cutting process, so the most satisfactory way of cleaning risers is to sandblast the necks, because this removes practically all of the sand.

Cutting Risers While Still Warm

Whenever it is practicable to cut the risers while they are still warm it is desirable to do so, because there is a saving of approximately 10 per cent in gas consumption. This is because the excess heat renders the slag more fluid, thereby improving the cutting efficiency. It is difficult to bring hot castings to the cutting frames, and the subject of hot cutting

is at the present time perhaps of more theoretical than practical importance, but this is a subject that is receiving attention, and it is by no means assured that it will remain in the theoretical category. It is decidedly something to keep in mind, and whereever feasible the cutting of warm or hot risers will undoubtedly repay the foundry manager for a reasonable amount of trouble in handling the work.

One of the most interesting and useful developments in the study of oxyacetylene cutting practice in foundries is the segregation of castings having risers that are approximately of a size, so that the operator can use the correct blowpipe tip and gas pressure. Where the castings are not segregated, if there is any considerable variation in sizes, the tendency is for the operator to select a tip that is capable of handling all the work, and the pressures naturally are set to enable him to cut the largest of the lot. It is easy to see how this might result in serious waste of gases.

Segregating Castings Into Sizes

There are many foundries in which some risers will be from 6 to 8 inches in thickness, while the bulk will be only 2 to 3 inches in thickness. There will also be a considerable assortment of risers of intermediate thicknesses. If a blowpipe is set so that it will cut the 8-inch risers, the full gas flow will be at the rate of not less than 700 feet of oxygen and 50 feet of acetylene per hour. For cutting the 2-inch risers the gas flow should not be greater than 200 feet of oxygen and 30 feet of acetylene per hour.

The segregation of castings into graduated sizes has been adopted by many progressive foundries and might well be adopted in many others. Little labor is required to land the castings in groups. Additional labor certainly would not exceed one man, whose compensation would be probably 40c per hour.

Assuming that the castings have been properly segregated and that the cutter has disposed of the heavier risers with the most efficient pressures, he next adjusts his blowpipe for the cutting of the largest remaining series. This becomes a natural and justifiable thing to do where there is considerable cutting in each series, but it would not be either natural or economical if

the castings were indiscriminately handled. If the cutter has an hour's work on the 2-inch risers, it is quite clear that in that hour he saves the difference between 700 cubic feet of oxygen and 200 cubic feet required for the different sizes. The actual saving is 500 cubic feet or two and one-half times the volume of oxygen required for the work on the 2-inch risers. The saving in acetylene is 20 cubic feet. These savings at the current prices of the gases amount to between six and seven dollars.

It would be difficult to segregate risers into a great number of groups, but it should be possible to use certain definite sizes of risers in the molding operation to facilitate separation at the cutting frame. Four groups, which do not require an excessive amount of handling for the average foundry might be sorted to take in risers of 2, 4, 6 and 8-inch risers.

With the segregation of risers into such groups, and the use of tips and pressures best suited for cutting each group, the savings alone should run from $15.00 to $20.00 a day for each operator. Such savings are well worth the consideration of foundry managers. Though there are many foundries that have adopted the segregation of castings as the orderly and economical way of handling cutting, I believe that only a few managers have a real conception of the amount of gas they are saving.

Foundrymen cutting risers 8 inches in thickness and larger can well afford to insist upon their operators' cutting with the proper tip and setting the regulator at the proper pressure for a given size, even though only one of a size is cut. A riser 10 x 12 inches costs more than $1.50 to cut. The total cutting time for such a riser would be about 10 minutes. The time necessary to get the correct adjustment would certainly not be more than one minute, and this at a 60c an hour rate for a cutter, would cost one penny. By getting the best pressure for the work the saving would be at least 10 per cent over the cutting costs when the operator depends on haphazard guessing, because he must always be sure of sufficient pressure, which, in such castings, means excessive and unnecessary pressures.

Speed Not Dependent Entirely on Pressure

Some cutters believe that excessive pressures enable them to cut faster. This is a fallacy, because in cutting a given thickness of metal the rate of cutting does not depend on the quantity of oxygen but entirely on the time interval required for the chemical reaction which takes place. When excessive pressure is used, a large amount of oxygen is blown through the cut without in the least helping to promote oxidation. The excess oxygen might have a slight beneficial effect due to the higher velocity of the gases which tends to blow the molten oxide from the kerf, but any such gain is not worth the oxygen wasted on it; besides, where correct pressures are used there should be no difficulty from choking of the slag in the kerf. Moreover, it has been noted in a good many instances that correct pressures are not only more economical in gas consumption than excessive pressures, but result in even better cutting speeds.

Still it should be borne in mind that a cutter will be almost sure to get into difficulty if his pressures are not high enough. Doubtless, it is his knowledge of this fact that actuates the operator who guesses at his pressures in almost a universal tendency to allow a generous margin of safety resulting in excessive pressure and consequent waste of gases. Blowpipe manufacturers provide cutting pressure tables for use with their equipment and the pressures prescribed in these tables for different thicknesses of metal should be closely observed and followed. As it is always possible that pressure gages may get out of order, it is advisable to have the gages checked against a good master gage at frequent intervals, or in the absence of this service, operators should be checked by a test engineer who will direct them to cut under varying pressures until the best effective pressure for each thickness of metal is noted. If the best effective pressure does not check with that called for by the manufacturer of the blowpipe it is pretty conclusive evidence that the gage is not functioning accurately and that it should be either replaced or adjusted.

Operators who are using correct pressures for cutting sometimes encounter difficulties due to blowholes in the riser. While

it may be possible by the use of excessive oxygen pressure to continue the cut across blowholes of even an inch or more in diameter, such defects in risers always give considerable trouble and there is a much better way to handle the situation than by a wasteful use of oxygen.

When a cutter who is using the correct pressure encounters a blowhole he should at once change his position to permit of cutting from the other side of the riser, as this has been found much better than trying to "hog" his way through after hitting an obstruction. Experienced operators can "feel" blowholes and such operators switch to cutting on the opposite side of the riser with practically no loss either of time or of gas.

Cutting Through Blowholes in Risers

Some operators instead of stopping a cut when they "feel" a blowhole and starting from the opposite side, work around the riser, retarding the bottom of the cut as they advance the torch tip. This tends to leave a more open kerf and to keep the oxygen jet away from the blowhole until enough metal has been cut away to permit the cutting jet to work altogether on solid metal instead of encountering the blowhole, so the cutting operation can be completed normally. This same scheme of cutting around a riser is often used in cases where heavy cutting, such as 20 inches or more, is required, yet where the facilities do not permit an ample supply of oxygen for this heavy work. By cutting around the riser the actual depth of the cut at any time is not over two-thirds the thickness of the riser. This cutting around the riser is an interesting trick and takes care of difficult situations, but it is not the best practice, which is to have a big enough oxygen jet and a sufficient supply of oxygen, through a pipe line or manifold, to permit of straight-through cutting.

The cost of making the cut is not the only problem involved, because if a cut is not along the line desired additional cutting will be required to trim it to shape, or the excess metal must be removed by grinding. The major reason for using cutting benches or frames is so the work will be at a level where the operator can control the direction of his jet exactly and remove the

riser with one clean cut. Incidentally, the operator will naturally work faster and will probably pay more attention to the gas pressures, if he is working in a comfortable position.

Theoretically there seems to be no limit to the thickness which can be cut with oxyacetylene flame. Within the past year or two, cuts have been made measuring 3 and 4 feet in depth. The quantity of oxygen required for such heavy cutting requires special provision for regulators, manifolding of cylinders, etc. This kind of heavy cutting also necessitates the use of special tips so that all the oxygen the torch can handle may flow through the jet. Unless a foundry is properly equipped for cutting exceptionally heavy risers and has operators who are experienced in the work, it would probably pay to call in a special operator whenever one of these difficult cutting jobs is encountered. Study of heavy cutting is being made, and apparatus capable of cutting almost any riser that can be poured will probably be available within the next year.

Effect of Cutting on Metal

Anyone who has observed oxyacetylene cutting probably wonders what effect the cutting has on the metal. It is safe to say that dozens of investigations have been conducted on this question, as it is a particularly important one in certain lines of cutting. In the cutting process the metal is heated to a high temperature in the region of the reaction, but it cools relatively fast because the body of the casting is cool and conducts the heat away from the cut surface. On this account the extreme edge of the cut, where the intensity of heat has been greatest and where there is also a cooling action from the air, is of fine grain structure and somewhat hard. The effect of heat on the grain structure is observed under the microscope to extend from the cut surface to a point about three-sixteenths of an inch from the cut surface, beyond which all evidence of granular metamorphosis seems to cease. It is clear, therefore, that the hardening effect of cutting is localized, and if even an average machine tool cut is taken across the surface of the oxyacetylene cut, all of the affected metal is removed. Besides the effect on the grain structure, the cutting heat produces an-

other effect on castings unless proper precautions are taken—it sets up strains of a more or less serious character. These tend to warp the castings, the degree of distortion depending largely on the shape of the section of the casting where the heat was applied.

On some castings the warpage is considerable and steps must be taken to overcome the difficulty. One way of doing this is to heat the entire casting to a dull red (at which temperature the cutting is done), after which the casting is permitted to cool slowly. Another way is to cut small sections at a time, permitting each section to cool down completely before undertaking the next cut. This method does not entirely relieve the strains in the casting, but largely prevents the warping. Where long cuts are made warping is primarily due to the fact that the body of metal is cold and that only one edge is heated. So long as it retains its heat the cut surface is capable of adjusting itself to the main body of metal, but when the metal along the edge of the cut is cooled down to the point where it develops appreciable strength, it no longer yields but pulls as the metal continues to contract in cooling. This effect is exactly the same that occurs in the cooling of a bar of metal, except in this case the bar is really an integral part of the whole. If the main section is relatively light and is long, the pull of the section which has been heated will cause warpage. If the main section is relatively heavy, there will be no warpage but there may be strains.

A thorough annealing of the casting should restore the proper grain structure of the metal and should entirely relieve all strains. If the casting is warped, however, relieving the strains by annealing will not bring the casting back to its original shape.

To conclude the discussion of the cutting process, the writer desires to mention a relatively recent development, namely cast iron cutting. Apparently, this form of the cutting process is not advantageous for foundry use at present, as the cutting action is slow as compared to the reaction in cutting of steel, and much larger quantities of oxygen are required. Cast iron

cuts can be made, however, which closely resemble steel cuts, being real cuts and not merely sections melted out.

Welding Applications

Oxyacetylene welding is not used in the average steel foundry to the extent that the cutting process is employed, but it merits most careful consideration in foundries of all kinds. When properly made, the oxyacetylene weld should be as strong as the original base metal of a steel casting. It is highly important, however, that the proper filler rod should be used in the welding of steel castings. It never is advisable to use Norway welding wire, for example, as the deposited metal would be wrought iron and, therefore, of different composition and strength than the metal in the casting. If, however, the welding rod is properly selected to give a deposited metal similar in composition to that of the casting, the oxyacetylene weld metal can be counted on to thoroughly bond with the original metal and to be of almost the same composition. Being in a cast condition, the deposited metal should be equal in strength to the original casting.

In welding we must watch the effect of heat on the casting to avoid warping and the setting up of strains. Neglect of this precaution accounts for many unnecessary failures of castings which have been otherwise correctly oxyacetylene welded. Where welding is done on a large section, a considerable area will naturally be at quite a high temperature, and on cooling down will undergo severe contraction. If this effect of the heat is permitted to cause failure of the metal, it is the fault of mechanics and is not a failure of welding. There is one certain way of preventing this bad effect of heat, and that is to have the entire casting heated so that the cooling down will be uniform in all parts. Incidentally, if the quantity of welding amounts to even 3 per cent or 4 per cent of the total volume of the casting, the heating of the casting in a furnace or by an oil or gas and air heater will probably save enough oxygen and acetylene to more than offset preheating cost. Preheating is advised whenever castings are oxyacetylene welded, and if it is not practicable to completely preheat a casting it should at least be lo-

cally preheated so as to make sure no serious strains will be left in the casting when it has cooled down.

It is of utmost importance that the cooling down of welded castings should be a slow process, and to insure slow cooling a welded casting should be covered with sand or should be placed in annealing ovens or bins. By doing this the casting will cool down from the annealing temperature so slowly that the cooling will be uniform.

In gray iron castings oxyacetylene welding is used almost altogether. In this work the welding rod should be made of gray iron of excellent quality that is high in silicon content, and a flux should be used to work the oxide out of the molten bath.

Preheating is even more important in the welding of gray iron castings than in the welding of steel castings, and the subsequent annealing is equally as necessary. The actual making of a weld in gray iron is an easy operation, though it is often a long-drawn-out and hot one. In gray iron the resulting weld should be of even better quality than the casting, because the deposited metal can be cleaned so thoroughly.

In most gray iron foundries the welding is being placed on a production basis, the castings being heated in annealing ovens and then carried to the welding stations where they are properly welded. They are then returned to either the annealing bins or to sand piles where they are covered and allowed to cool down slowly. In some gray iron foundries the number of acceptable castings per hundred poured has risen very decidedly through the use of this real production welding.

Welding in steel foundries can well be given fresh consideration, because through use of a three-section manifold sufficient oxygen to do the welding will be obtained from the cylinders after they have been utilized for the cutting work. This oxygen may be considered as of no cost, because it is pure salvage. It does not pay to take the cylinders from one manifold to another, or to carry them from a cutting station to a welding station, but it does pay to save this gas if a three-section manifold is installed. In view of the excellent quality of

the deposited metal obtained by the oxyacetylene process, the whole problem of welding should be thoroughly studied by foundry managers. In some cases, where welds are made by other processes, it will pay to add a layer of oxyacetylene welding owing to superior machining quality of the deposited metal.

Maintenance and Repair Work

Attention should be called to the numerous uses for the oxyacetylene process in maintenance and repair work. As this kind of work is separate and distinct from production work, it will pay to have a skilled repair welder and cutter rather than to depend upon one of the regular foundry operators. It is well for such a man to be a good mechanic in addition to being an oxyacetylene welder and cutter.

Oxygen alone is used for burning out furnace tapholes when they become badly plugged with frozen metal. Oxygen alone is also used for drilling into skulls and salamanders. These uses for oxygen are assuming great importance in the steel mills and oxygen burning is also becoming more and more a recognized operation in modern foundry practice.

The oxygen cutting torch is used in cutting out structural steel, sheet steel or cast iron parts to be removed in demolition work. When making changes in plant structures (such, for instance, as the installation of new cranes) old columns, frames, etc., are frequently removed, and these changes can be made on a very few minutes' notice with the cutting torch used either for burning out rivets or for cutting through sections. When new parts are ready for installation, changes can frequently be made during the noon-hour, or on holidays, thus saving much productive time.

Cutting is used in removing parts of furnaces, cupolas, gas producers and numerous other kinds of equipment employed in foundries. Constructively it is used in shaping structural and sheet steel which is to be used in new equipment.

Oxyacetylene welding is being used more and more around all industrial plants for welding of broken parts, welding patches into sheets when corrosion has necessitated cutting out bad spots, etc.

In new construction welding is most useful for installing pipe lines, making steel tanks, bins, oil receptacles, gear guards, etc. The master mechanic who understands the possibilities of oxyacetylene welding can keep a welder busy all of the time around a foundry. In some places the oxyacetylene welding torch is being referred to as a "one-man machine shop," which clearly indicates its adaptability to almost any welding or cutting problem that is likely to arise.

Recapitulation

1. In the larger foundries a new type three-section oxygen manifold will pay rich dividends on the investment and provide oxygen for welding at almost no cost.
2. Piped oxygen and acetylene installations are desirable in large foundries because they obviate handling cylinders for regular production cutting and welding in the foundry proper.
3. To obtain the best results oxyacetylene equipment must be regularly inspected and properly maintained.
4. The managerial phase of gas cutting and welding is as important as the technical phase in securing maximum efficiency and economy.
5. Repair welding in the foundry is well worth while and should be under the supervision of the master mechanic rather than under a production official.
6. Oxyacetylene cutting of cast iron is often a useful operation but it is not economical for regular cutting of risers in gray iron foundries.
7. New uses of oxygen and acetylene are being discovered almost daily and foundries can well afford to follow the lead of steel mills in adopting many of the new uses and practices.
8. Segregation of castings according to the sizes of the riser necks may be counted on to more than repay the expense incident to such segregation.
9. Proper elevation of work and comfort of operators are worthy of close attention.
10. Recent developments in the oxyacetylene welding and cutting industry are such that no one can safely accept conclusions as to its limitations, unless these conclusions are based on a knowledge of present conditions. For this reason most foundrymen and others can well afford to make an entirely new survey of cutting and welding with regard to the possibility of introducing or extending special applications of the processes in their establishments.

Discussion—A Managerial Study of Oxyacetylene Cutting and Welding in the Foundry

R. A. BULL.—There is a little additional information I would like the speaker to give us if he can. He speaks of the composition of welding rods as being a matter to be carefully considered. In his experience what has he found, for example, to be the desirable composition of a rod for a steel casting, say a .25 carbon, 0.65 manganese and 0.30 silicon?

G. O. CARTER.—A study of the research end of a welding rod has developed the point that the usual Norway iron which is used is lacking in strength because it has no carbon. When you use the ordinary steel rods that are sold nowadays, they almost always wind up with the carbon burned out. This new rod which has been developed—in fact, is about to be introduced quite extensively—has 0.65 manganese. There is no reason why it cannot be made 0.25 carbon. The tests which have been carried on over a period of years show it to be very clean, and every operator who has used that rod has obtained better results.

P. BENDIXEN.—I would like to ask the gentleman the desirable temperature of the room where you have your manifold.

MR. CARTER.—I think the average room temperature of 70 degrees is easy to hold. It is one that is not hard on the men and you have practically no difficulty from the operation of regulators at such a temperature. We know that in very cold weather, when it is freezing outside, the efficiency is not what it is at summer temperature.

MR. BENDIXEN.—What percentage of the capacity of the cylinders is it possible to bring under practical results?

MR. CARTER.—The capacity of a standard cylinder is 2000 pounds pressure; but when a man uses a cylinder to 30 pounds pressure, he gets all he pays for.

P. P. ALLEN.—I would like to ask Mr. Carter what success the foundries are having in welding malleable castings. We have tried to do it on light castings, from ⅛ to ½, but found we would have to anneal them.

G. O. CARTER.—The question of welding either white iron or malleable castings is one that has been fought over ever since oxyacetylene has been known. It never has been successfully done. Our experience is that the brazing is as strong as the casting itself. Where emergency repair work is the rule rather than production work, brazing is used very extensively.

A. S. KINSEY.—I think it well to point out the fact that that so-called brazing really is welding. It is not a correct statement in any sense of the word. They use bronze for that and it is welded into the cast iron to make the repair. The cast iron should have a tensile strength around 20,000 pounds per square inch. The tensile strength for bronze runs sometimes as high as 60,000 pounds; so you can see that the strength factor is well taken care of. What Mr. Carter says about the difficulty in welding a finished malleable casting is absolutely correct. We know that the problem there is to take care of the temper carbon and combined carbon. There is no known way to weld cast iron into malleable after the casting has been malleableized. However, the people who are making malleable iron castings and finding defects in the casting before they are malleableized are repairing them with the oxyacetylene torch with considerable success, and they do not need to use bronze.

I would like to emphasize the utility of the oxyacetylene torch as I have seen it in the steel foundries for repairing castings. Now, there are other uses than merely filling blow holes. It would seem to me that the principle of operation should be to try to leave the casting, although repaired, in as good a condition and as similar in characteristics as was originally intended. For instance, if it has a tensile strength of 50,000 pounds per square inch, the welded part should be as high. If its elongation runs 25 per cent, it should be of about that elongation. Some welding increases the tensile strength by making it hard and brittle, but at the expense of the ductility of the job. Its elongation has gone down to

five or eight per cent, where it originally was 25. The oxyacetylene torch will weld, with a proper welding rod, a break of that kind, keeping the tensile strength up to nearly 100 per cent. There is a way of running it even higher than the 100 per cent by using a special welding rod.

Flask Equipment for Molding Machines

By Arnold Lenz, Saginaw, Mich.

The keen competition of the past year with its resulting low casting prices has taxed the ingenuity of every foundryman and forced him to be ever on the lookout for new developments in the industry. This condition has made it necessary that the foundryman keep himself not only informed in regard to the latest models of molding machines and kindred equipment, and adopt them wherever possible, but that he also recognize the importance of bringing the minor tools and plant equipment up to the same standard of efficiency.

Flask equipment often receives only passing consideration, and it is not an uncommon thing to see a new flask of an antiquated design used in connection with a molding machine and patterns of the latest model. In order to operate a modern molding machine at its highest efficiency the flask equipment must be equally modern. Many good molding machines have been condemned because of poor equipment.

Avoid Use of Gaggers

The greatest efficiency is possible when the operations are reduced to filling the flask with sand, jolting, squeezing, stripping or rolling and drawing the pattern. The setting of gaggers, which requires some skill and tends to slow up the operations considerably, should be eliminated, and it is possible to do so on the majority of jobs. How far this can be carried in production work is shown by the castings in Fig. 13, which are made in a foundry that has discontinued the use of gaggers entirely. The advantage of this must be apparent to every practical foundryman; it leaves the sand heaps free from a lot of interfering material and reduces the ramming to a few simple operations which any intelligent laborer can learn and perform at high speed within two or three days.

The castings are produced in a continuous foundry and the

flasks are rammed up before they have completely cooled off. Only in exceptional cases is wetting or clay washing of copes resorted to, and then only at certain points. The thin section work does not permit the use of heavy bonded sands and, contrary to what might commonly be supposed, the sand in use is no stronger than that used in the average foundry.

There is a great difference of opinion as to what constitutes an ideal flask. In a jobbing foundry a cheap wood flask may be most satisfactory for a one-piece job, or it may be a solid or assembled cast iron or steel flask to serve a number of patterns. The snap-flask, solid cast iron, cast aluminum, or pressed steel flasks for small castings are equally good in jobbing and production work. A wood snap-flask gives excellent service on a combination jolt-squeezer, especially if used in connection with steel bands.

The greatest difference centers around the production flask larger than the common snap-flask sizes, as used on molding machines. The writer's conception of a good flask for production work is a rigid metal flask designed so as to allow just enough sand under the pattern in the drag to prevent runouts through the bottom, and swells or other irregularities caused by insufficient sand. The joint of the flask follows the outline of the pattern as closely as practical, yet leaving sufficient space to permit proper ramming and prevent runouts. It has the necessary handles and trunnions for handling, a perfectly machined joint, and interchangeable pins and pinholes. The cope has just enough bars to carry the sand and keep the mold from coping, but not so many as to encumber the ramming and shaking out. The bars are so designed and placed that no tucking of bars and no gaggers and nails are necessary.

Laying Out of Flasks Is Important

The flasks in a production foundry form such an important part of the equipment that they should be laid out by one who is thoroughly familiar with the available machine and handling equipment, and with whom the securing of sand in a mold is past the point of guesswork. As a rule too much of

this work is left to the patternmaker, although there are few patternmakers who are familiar enough with molding and the details involved in securing the sand in an intricate cope, to build a good flask pattern. It seems to be a hard matter to break away from the old jobbing work cope, in which the bars are nailed, bolted, or cast in, five or six inches apart, irrespective of the contour of the pattern.

The builder of a flask for molding machines should also be acquainted with the peculiarities of jolt-rammed molds. If a cope is rammed by hand the sand will pack tightly against the bars, and in case of wetting or clay-washing the sand will adhere to the bars. This is not true with a jolt-rammed mold. On close investigation a slight clearance will be found between the rammed sand and the bars or sides, due to the vibration set up in the flask by jolting. The squeezing or butting off after jolting will pack the sand against the bars and sides in the upper part of the mold, but unless the cope is quite shallow the pressure will not be sufficient to overcome this condition next to the pattern. This accounts for the many drops on the joint if sand strips are lacking. This vibration can be partly overcome by clamping the flask to the patternplate while jolting. I have also found that by regulating the speed and length of the stroke of the jolt cylinder, according to the weight of the pattern, the vibration can be reduced to a minimum. This is especially true if attention is given to fairly equal distribution of the weight. Where the weight is all on one side of the jolt cylinder the table will develop a rocking motion which always results in a poorly rammed mold.

Materials for Flasks

In the past, cast iron has been considered the standard material for production flasks, but of late this has been replaced in many instances by cast steel. This is especially true in continuously operated foundries where a limited number of flasks are used from two to four times a day, and strength is of utmost importance. In the last few years the fabricated steel flask has come more and more into use, and from the

point of weight and indestructibility it is quite satisfactory, but unless it is constructed of extra heavy material it sooner or later will develop a warp which, in addition to causing a bad fit at the joint will spring in jolting or squeezing, and cause drops in the cope, also clamping off in the drag.

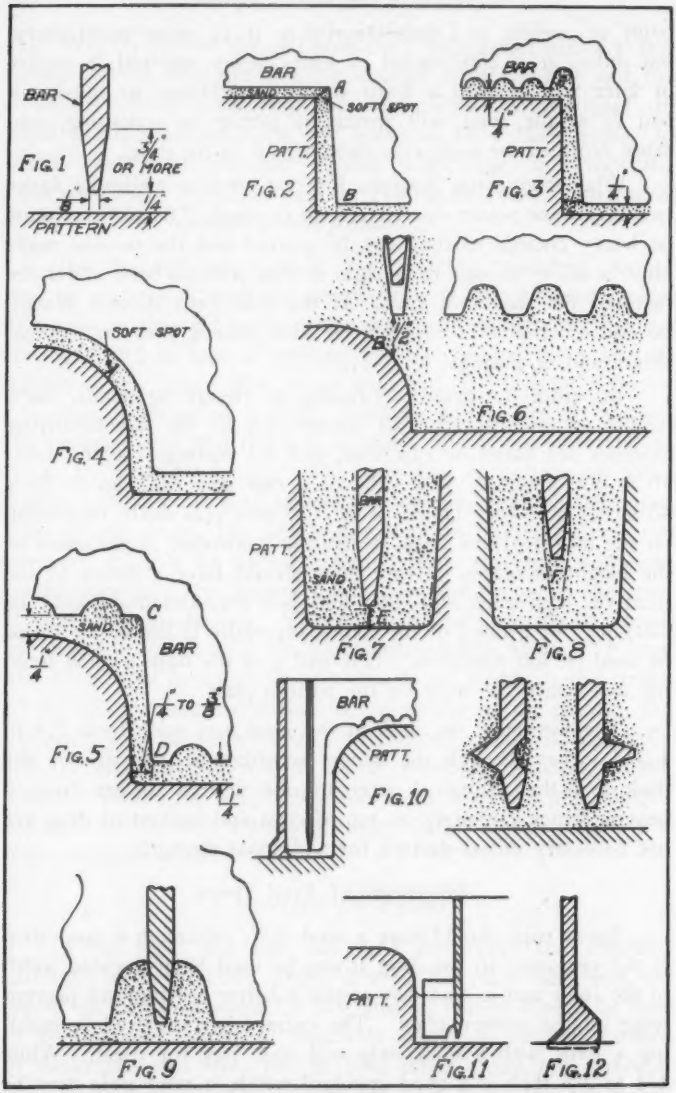
When laying out patterns for cast steel or malleable flasks two important points should be kept in mind: The sections must be heavy enough so they can be poured and the outside walls must be heavy enough to be rigid so they will not bend under the maul of the shake-out crew. If the side walls become dented, no end of trouble is experienced with binding pins on the machines and in closing.

In order to avoid confusion in describing walls, bars, flanges, trunnions, etc., all dimensions in the accompanying sketches are based on cast iron, and for castings ranging from 10 to 500 pounds. The walls of a cast iron flask up to 24 x 48 inches may vary from 1/4 to 7/16 inch plus draft, depending on the height of the flask, decreasing somewhat in thickness as the height increases. Every flask should have a flange at the joint on both cope and drag and both cope and drag should be machined, or ground at the joints, especially if the flasks are to be used on jolt machines. This will give the flask a good bearing and retard the wear on the pattern plate.

The section of the flask at the joint may vary from 7/8 to 1 1/4 inches through the flange, according to the size of the flask and the additional strength one desires to get from a heavier flange. Flanges on top of cope and bottom of drag are not necessary unless desired for additional strength.

Advantages of Sand Strips

Every cope should have a sand strip. Although a sand strip is not necessary in the drag it can be used to give extra width to the joint and in this way assure a better bearing and prevent wear on the pattern plate. The extra labor involved in molding a flask with a sand strip will soon pay for itself. While 1/4 to 3/8 inch is a good standard width, a sand strip may be made 1 to 1 1/2 inches wide at certain points in order to make



FIGS. 1-12—TYPICAL ARRANGEMENTS OF BARS IN FLASKS, ILLUSTRATING PROBLEMS ENCOUNTERED BY MOLDERS

a lift from the joint. In this manner it will often replace bars in a bad corner, or avoid using nails and gaggers.

After considerable experimenting, the writer has found that it is possible to lay out the bars in a flask so that tucking of bars and setting of gaggers can be eliminated. It is not always possible to eliminate the nails because the projection on the bars may have to be so light that it would be impossible to keep it from breaking off. In this case a cast steel flask has the advantage over one of cast iron. Quite often a nail or spike can be cast into the bar or welded on, but this is not always practical.

Some foundrymen may think it is too much bother to lay out such a flask, but no matter how busy one may be, one half to five hours devoted to laying out a flask is time well spent.

Although each job may have its own problem it is possible to apply certain rules on every job. For example in Fig. 1 the sand will ram solid under a bar 5/16 inch thick if the bar is tapered down to 1/8 inch next to the pattern and the space between pattern and bar is 1/4 inch. While at 3/16 inch the sand will still ram under the bar it is liable to be a little soft, but would be all right over coreprints and on the joint. The taper from 1/8 inch to the thickness of the bar should not be less than 3/4 inch to give the sand a chance to grip the bar.

Figs. 2 and 3 show a bar over a sharp corner. To avoid drops at *B* it is necessary to run the bar into the corner as close as possible and also to avoid damaging the pattern by hitting the corner when setting on the flask. About 1/2 inch has been found close enough to hold the sand and clearance enough to readily release the casting from the flask. A bar following the pattern as in Fig. 2 will produce a soft spot at *A* unless the sand is tucked under the bar. The reason for this is that in jolting the mold the sand will settle considerably from *A* to *B*, but the sand above *A* will not settle down sufficiently to fill in the space left by the settling sand. If this bar is cut out at *A* as in Fig. 3 this soft spot can be avoided. The same condition still exists, but the soft spot will be found up in the extreme corner of *A* and too far away from the pattern to affect

the casting. The cut in the bar at *A* may range from 1/2 inch deep for a low pattern to 1 inch or more for a high one.

A similar condition exists with a pattern as shown in Fig. 4, the bar running parallel with the pattern. Fig. 5 shows the corrected bar. In this case the casting will not bind in shaking out and there is no high corner to be damaged in setting on the flask. The corner *D* therefore can be moved to within 1/4 inch to 3/8 inch of the pattern. The bar need not follow the radius of the pattern because the mold forms an arch, the base of which will be sufficiently supported by the corner *D*.

If it can in any way be avoided a bar should never be run across the radius of a rounded part of a pattern in the position as shown in Fig. 6, because the distance the bar has to be

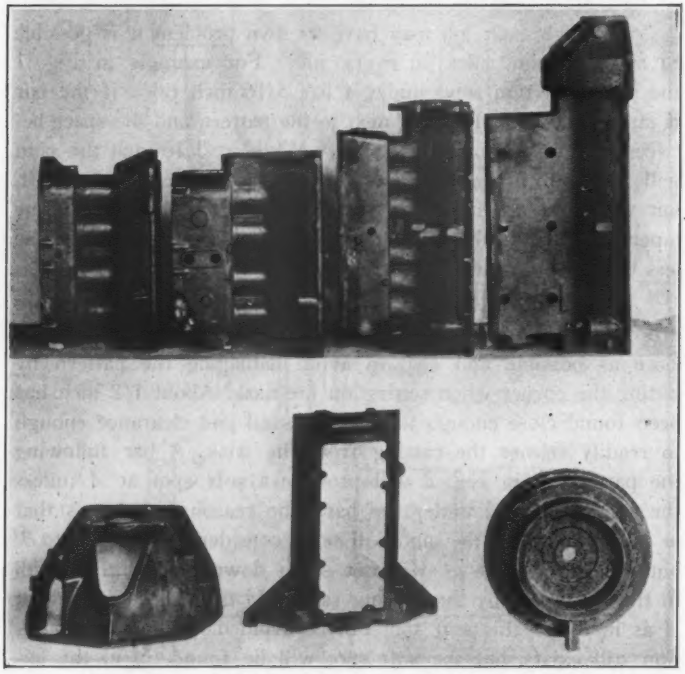


FIG. 13—CASTINGS MADE WITHOUT THE USE OF GAGGERS

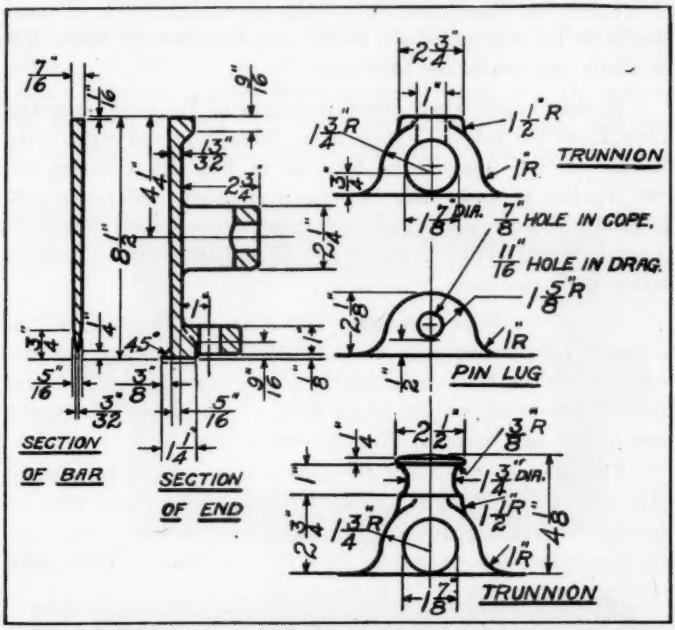


FIG. 14—TRUNNION AND PIN ARRANGED FOR NONINTERFERENCE

kept away from the pattern to insure solid ramming without tucking makes it of little use except where the bar is placed to prevent coping. However a bar in this position can be brought within 1/2 inch of the pattern if the bars are notched out as in Fig. 6. This permits the sand to feed through from the high to the low part of the pattern.

All bars should be notched the full length wherever possible as this gives the sand a better chance to ram under without reducing the lifting power of the bar. This is best illustrated where a bar is used in a pocket as in Fig. 7. If a solid bar is run within 1/4 inch of the pattern the sand is liable to spit at *E* and fall away on one or both sides of the bar. This can be largely prevented by notching, as at *F* in Fig. 8, giving the sand on both sides of the bar a chance to bind together at *F*.

Where two bars cross each other as in Fig. 9, one of them should be cut out as shown in the sketch, otherwise there will be a soft spot where the bars join.

In deep copes where there is danger of the sand dropping away from the side in rolling over, three cornered strips may be cast on the side of the bars, as in Fig. 10. Grooves cut into the bar at times may be more convenient and prove just as good. Care should be taken that the strips are not placed so close to the edge of the bar that they create a parting and so defeat their purpose.

At times it is not necessary and often not desirable to run a bar or a projecting spur or chuck the full height of the pattern because too many bars interfere with ramming and shaking out and add to the weight of the flask. In such cases the upper part of the bar is cored off as shown in Fig. 11.

The sand strip is most effective if it is tapered to a sharp edge next to the pattern plate. To avoid chilling the edge of the sand strip, which would interfere with machining, the casting should be made as in Fig. 12. This will leave a sharp edge after the surplus stock is machined off.

Equipment Should Be Interchangeable

It is a great advantage to have all equipment interchangeable. Certain standards therefore should be adopted at the start. Closing pins and pins in the pattern plates should be made standard. This enables one to keep a small stock of pins on hand so that bent and broken ones can be replaced without delay. A flask with the pins in the center is easier to close than one with the pins at one side. On most jobs handled with a hoist, this interferes with the trunnions. Fig. 14 shows a trunnion that will permit the placing of both trunnion and pin directly above each other without interference. One of the trunnions is used in connection with a spring bail or a hinged bail and has proved safer in handling than the other type which is used with a sling. The trunnions and handles are made with cores and are rammed up in the mold. One or two sets of coreboxes will be sufficient for a great variety of flasks.

No flasks should be drilled without a drill jig and whenever possible the drill jig should be made before the pattern plate is drilled. A set of hardened drill and ream bushings with a standard outside diameter should be made. By making the holes in the drill jigs, which may consist of plain flat bars to correspond with the outside diameter of the bushings, one

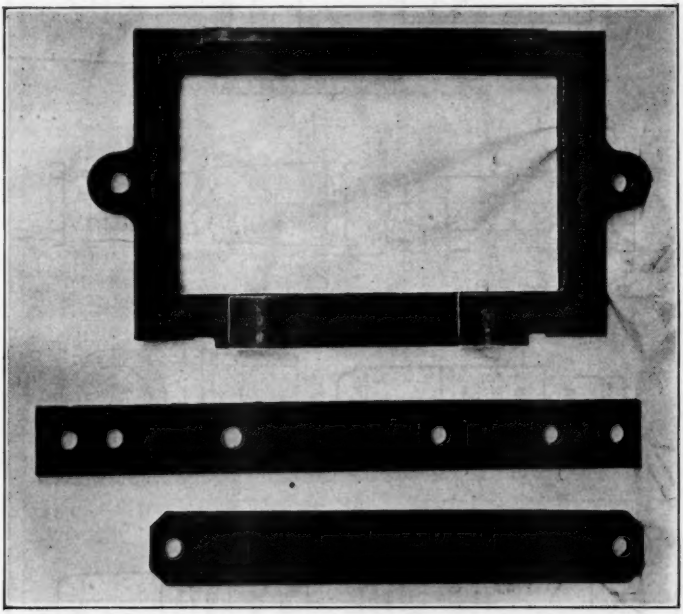


FIG. 15—THREE DRILL JIGS USED FOR PATTERN PLATES AND FLASKS

set of bushings will be sufficient for a number of drill jigs. Fig. 15 shows three drill jigs, one of which is for several jobs, and also a more elaborate one for a cylinder flask.

The pin lugs on the flask should be of a standard thickness so if a removable closing pin is used and the same is secured by a key a standard size slot will make all pins interchangeable.

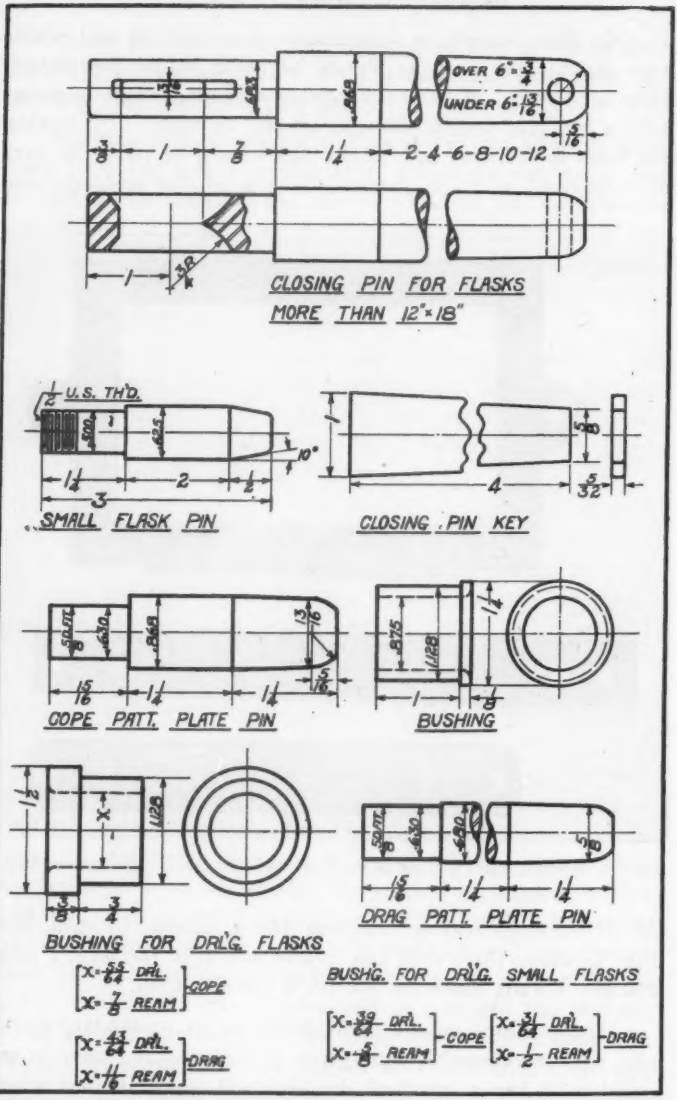


FIG. 16—A SET OF STANDARD PINS FOR COPE AND DRAG PATTERN PLATES ALSO PINS FOR CLOSING MOLDS

Two sizes of closing pins are sufficient, even in a large foundry covering a great variety of castings of medium weight. One size can be used for small machine and snap-flasks, and larger size for all flasks over snap-flask size.

Fig. 16 illustrates a set of standard pins for cope and drag pattern plates, for closing the molds, and for light solid

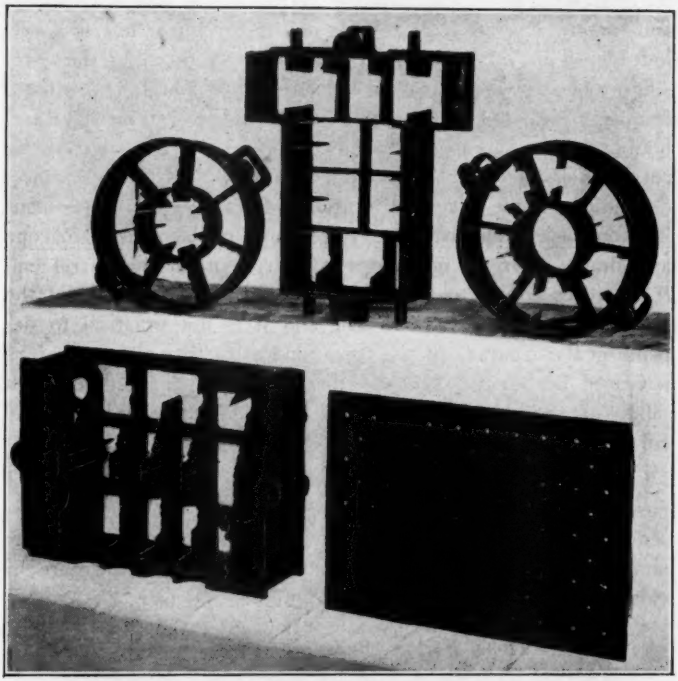


FIG. 17—A NUMBER OF TYPICAL METAL FLASKS

bench or snap flasks; also the necessary bushings for drilling and reaming the pattern plates and flasks. It will be noticed that all holes are reamed to size and the clearance is allowed on the pins only varying from 0.004 to 0.006 inch undersize. All pin lugs should be spot faced on the pin side to insure a good bearing against the shoulder.

A 7/8-inch pin with an 11/16-inch shank for large, and a 5/8-inch pin with a 1/2-inch shank for the bench and squeezer flasks are proving satisfactory. However the sizes are arbitrary, because any dimensions within reasonable limits will give good results.

Fig. 17 shows typical copes used in the foundry with which the author is identified. Of the round flasks, one is cast-steel and the other is fabricated. The one in the lower left is a cylinder flask in which the joints are used for locating the core. These openings are machined to close dimensions. The square, or crankcase end, cut in the drag, is machined on both sides and bottom, while the cope is machined only on the top edge of the cut for height, the two sides being cast with 1/4-inch clearance, depending on the drag for location sideways. The round openings on the cylinder barrel end are bored out accurately in cope and drag. There is no danger of a runout on the barrel end if the cores are up to size as they should be. On account of the large surface on the crank case end it is not practical to depend on the accuracy of the cores, and a backing plate therefore is placed behind the core and the intervening space filled with sand. A cylinder mold with the backing plate in place ready for pouring is shown in Fig. 18.

Fig. 19 shows a cylinder head mold in which the cope flask is also used as a core arbor on which the cores are assembled. The cores are assembled by girls in the core room and gaged from the pin holes. The molder sets the core by closing the cope over the drag on close fitting pins.

Good Bottom Boards Are Required

A bottom board usually receives only passing notice, although it may be quite a factor in the making of good castings. This is especially true in thin section work where speed and accuracy are combined. A good molder may be able to place a warped plate and wedge it up so it will not clamp off if he is given enough time, but where molds are rammed by unskilled labor and at high speed, straight boards or plates are absolutely necessary.

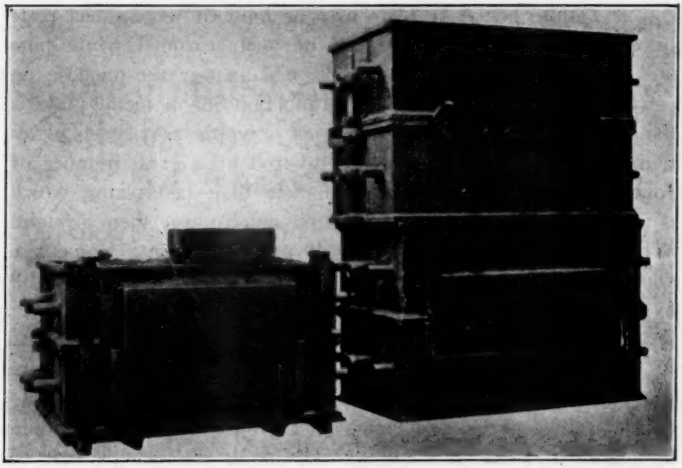


FIG. 18—MOTOR CYLINDER MOLD IN FLASK READY FOR POURING

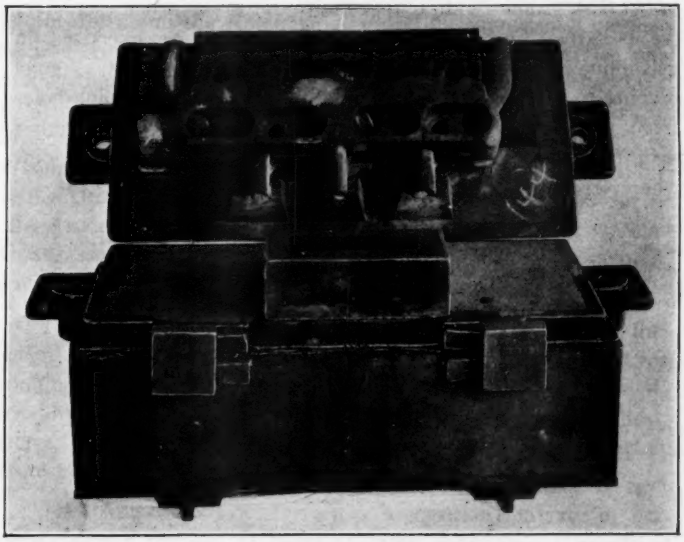


FIG. 19—CYLINDER HEAD MOLD WITH CORES IN PLACE

A bottom board or plate may be built of wood, steel plate or cast iron. Boards made out of well seasoned white pine will stay straight for quite a while and answer the purpose on certain jobs, but on a straight production job a metal plate is the most satisfactory and the most economical. Steel plates with angle or channel cleats are favored by a great number of foundrymen. They are usually lighter than cast plates, which is in their favor, but it is almost impossible to keep them straight. Where accuracy is desired I still prefer the cast iron plate wherever it is possible to use it. To avoid machining and still overcome the small irregularities of a cast plate, pads about 3/32-inch thick are put on the plates, as shown on the plate in Fig. 17. It is only necessary to true up these pads to insure a good bearing against the flask. If later on the plates should develop a warp the pads may be reground. The pads should be placed so that in clamping the mold, the clamps can be placed directly over them.

For best results it is necessary that the different bars in a flask come within the limits intended when set over the pattern. Special caution therefore must be exercised in machining the flask and in drilling the pin holes. It is good practice to machine the joint of the flask and drill the pine holes from the bars, using certain bars for locating points, rather than from the outside of the flask or from the unfinished joint where irregularities are the rule on the average flask.

Report of the Committee on Safety Code for the Use and Protection of Abrasive Wheels

There are a large number of safety codes and specifications in existence covering some of the more common hazards of industry. Some of these subjects are covered by a large number of such codes prepared by as many individuals and organizations and, as is to be expected, these codes do not agree. Sometimes the discrepancies are so great as to seriously inconvenience the manufacturers and users of the products in question.

A movement was inaugurated a few years ago to bring together the various interested parties to formulate a single safety code for each of these subjects that could be adopted as an American Standard. Early in 1920 this movement took definite form and the American Engineering Standards Committee was selected, through which this work should be carried on. Among the subjects taken up by this organization was the "Use of Grinding Wheels" and in April 1920 this body invited the International Association of Industrial Accident Boards and Commissions and the Grinding Wheel Manufacturers' Association of the United States and Canada to act as joint sponsors for a safety code for the use, care and protection of abrasive wheels. These associations both accepted the sponsorship and appointed a sectional committee to draft such a code.

This sectional committee consisted of representatives of the federal government, state regulatory bodies, manufacturers of grinding wheels and grinding machines, employers as users of grinding wheels, insurance interests, engineering and technical bodies, employees as users of grinding equipment and general interests.

The American Foundrymen's Association having in its membership a number of users of large quantities of grinding wheels was requested to appoint someone to serve on this com-

mittee. The writer was named to serve, and is pleased to have had the opportunity to serve the association on this very important subject. The first meeting of the committee was held in the Engineering Societies building, New York, Dec. 1 and 2, 1920 at which time much preliminary work was done and a draft of code prepared. A second meeting was held at the same place Feb. 8, 1921 at which time the code was further perfected. The code was then submitted to the grinding wheel manufacturers for approval, at a meeting held in Buffalo, March 11, 1921. A few changes were suggested which were resubmitted to the sectional committee by letter ballot and all conflicting opinions were finally settled. The code in its present form is the net result of this work and has been approved by the International Association of Industrial Accident Boards and Commissions, the Grinding Wheel Manufacturers' Association, the sectional committee by letter ballot and the American Engineering Standards Committee. Copies of this code can now be obtained from all manufacturers of grinding wheels.

C. H. GALE,
A. F. A. Representative

Report on Sand Reclamation Investigation of the American Steel Foundries

Prepared for the Joint Committee on Molding Sand Research of The American Foundrymen's Association and The National Research Council

Report of Sand Reclamation

To the Committee on Molding Sand Research of the American Foundrymen's Association and the National Research Council.

J. C. Davis, fourth vice president of the American Steel Foundries has kindly permitted a representative of the committee to make a digest of the sand reclamation work which has been carried on by the engineering staff of the American Steel Foundries under Mr. Davis' direction. Acknowledgment is also made to W. A. Janssen, assistant fourth vice president of the American Steel Foundries, for his helpful assistance to your representative in preparing this report.

Because of the scarcity of steel molding sand of the best quality and the problem arising from having to dispose of large amounts of refuse sand, this company has carried out an intensive investigation of methods of reclaiming the good material which is usually lost when the so-called refuse sand is thrown away.

After experimenting along many different lines and thoroughly going over methods employed in other plants, a process of reclaiming old sand called "centrifugal scrubbing" has been developed. After establishing the principle of this method, J. C. Davis designed and the American Steel Foundries took out patents covering equipment which permits the economical reclamation of old steel sand.

The notes which follow were taken from reports submitted by the various engineers of the company. Particular attention is

called to analysis of refuse sand which was used as a basis for the final solution of the problem.

Division of Report

Part I. Theory of sand reclaiming.

Part II. Centrifugal air scrubbing process.

Appendix I. Cost of reclaiming sand by the centrifugal air scrubbing process.

Appendix II. Description of proposed sand reclaiming unit.

PART I.

Theory of Sand Reclaiming

Closely associated with the theory of sand reclaiming are the reasons why refuse sand is no longer fit for further use for refuse sand is a cosmopolitan product for it contains both good and bad material.

Bad Material

A-1. Small free particles of fused fire clay, flour or other bonding material which has been rendered useless. Also an excess of this material when in good condition.

A-2. Small grains of sand which are covered by reduced bonding material, either fused or attached to surface of grains.

A-3. Large grains of sand which are covered by reduced bonding material, either fused or attached to the surface of the grains.

A-4. Combinations of large or small grains or both, fused together and covered with reduced bond material.

A-5. Foreign objects, such as scrap nails, chills, gaggers, spills, scale and others of similar nature.

A-6. Some fine particles of other material which has become fused or reduced or which is of such character that it will not bond, take high temperature or which is for other reasons unsatisfactory and therefore undesirable.

Good Material

B-1. Small free grains of good fire clays, flour or other bonding material.

B-2. Small grains of sand either clean or covered with good bonding material.

B-3. Large grains of sand, either clean or covered with good bonding material.

B-4. Combinations of large and small clean grains of sand or both held together only by the adhesive power of good bonding material.

A-1. In the above reclaiming process it is necessary to entirely separate and remove all A-1 particles because of its ob-

jectionable nature, reducing bond, reducing fusion point of sand, and filling up voids.

A-2. This item covers the small grains of sand which were originally included under B-2, but have been heated to a point to make the sand grains plastic and decomposed the bonding material has become attached. This material left in the sand means increased bonding material. This item is the most important one to be considered in sand reclaiming and no process will be satisfactory unless it is efficient in this regard. If it were feasible or in any way possible, the removal of A-2 material would simplify the process, but up to the present no method has been discovered which will separate A-2 from its companion B-2. If such a plain separation were developed which at present appears impossible, there would still exist an important barrier which would preclude adoption in practice. By far the greatest proportion of refuse sand is that included in A-2 and A-3. If all A-2 and A-3 material were removed in a reclaiming process by plain separation, the resultant yield in good material would be so reduced that the process would probably not be an economical one.

A-3. The condition of A-3 material is such that it is also necessary to subject it to a preparation process to break it down and remove the strongly attached objectionable matter, reducing it to A-1 and A-3, and as such it is easily susceptible to plain separation methods.

A-4. This item includes combinations of A-2 and A-3 and is a companion to B-4 except that the combination is supported by fusion instead of legitimate bonding action. To be handled with success it must first be broken down into A-2 and A-3 which in turn must be put through a preparation process to further separate them into A-1 and B-2 or A-1 and B-3. The A-4 combination is objectionable for the same reason as A-2 and also because a combination of grains assumes a very irregular shape and if the combination is allowed to continue growing, it would become joined with similar combinations. The principal objection, however, is the fact that irregular shapes provide a harbor for the lodgement of A-1 material and in

addition to its irregularity presents a difficult matter for proper bonding, making it imperative to use a larger amount of bonding material with a consequent deleterious effect.

A-5. This item includes all foreign materials which are in no form related to the original material. Its separation from the sand is a simple matter.

A-6. This item covers all material included in the division of bad material not included in any one of the preceding "A" items. There are certain minute impurities in new sand which are rendered entirely objectionable after being subjected to comparatively low temperatures and these should be removed in any process of reclamation.

Owing to cleavage plans, partially existent in some of the small new sand grains and the expansion and contraction caused by the heat of casting grains, break sometimes into small parts and again in some cases small particles are spalled off the edges of the larger grains.

Again there are minute particles of iron oxide or slag which must be removed. Owing to the fact that all A-6 material is very minute in size and cannot build up to form larger combinations, it is not difficult to eliminate. Any process that will effectively remove A-1 material will likewise remove A-6 material.

B-1. Under this item is included all the small free particles of good fire clay, flour or other bonding material.

B-2. Under this item is included the small or fine grains of sand which have not been subjected to a high temperature.

B-3. Is identical with B-2 except for size.

B-4. This item covers combinations of materials which have been described singly under B-1, 2 and 3. This combination breaks down in mixing, milling, or even by ramming.

It will be evident that the items listed both under the good and bad material are the simple forms which are encountered. It will also be evident that some material would literally be included in both the good and the bad material under the corresponding item, due to the fact that it is not wholly

in one condition. It is necessary, as indicated in the ideal theory of sand reclaiming, (as later described) to resort to some scheme of preparation as an important part of any successful process of sand reclaiming. The advantage of preparation to A-2 material is the fact that the yield of reclaimed product is materially increased by breaking up the A-2 material into its constituent elements, A-1 and B-2. When this division of A-2 has been made, the situation assumes a simpler aspect and it is not at all difficult to institute now an additional process of separation which will retain the renovated grains of sand B-2 and discard the fine particles A-1. Before leaving the subject of this item, it is necessary to make some remarks on the preparatory stage of the process. The decomposed bond A-1 is attached to small and large sand grains A-2 and A-3 in a very substantial and permanent manner and a process to remove it must be thorough, somewhat severe and even perhaps violent in order to remove the objectionable matter from the surface of the sand grains.

Ideal Theory of Sand Reclaiming

Refuse sand has been described as being divided into two broad divisions. From Fig. 1 an inference could be drawn that sand reclaiming should consist essentially of separating the good from the bad material. Early investigators were misled in the belief that a solution of the problem consisted solely in a simple separation process and they devoted their energies to perfecting apparatus to accomplish this purpose, but their fatal mistake was the simple fact that they failed to distinguish in their separation methods between the actual good and the actual bad material.

It can be clearly seen now why these efforts were not successful and why the progress made was very slow. In addition to misconception in theory, the early efforts were all directed to develop a one-stage continuous apparatus, so that refuse sand would continuously enter and reclaimed material be continuously ejected.

The theory of ideal sand reclaiming may be described as a composite process. The proper thing to do first would be to sep-

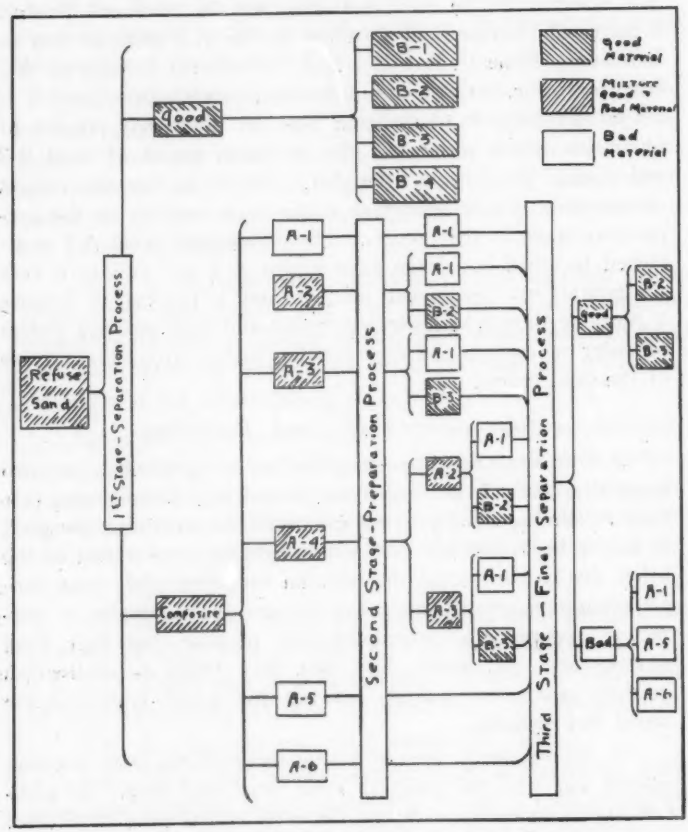


FIG. 1—DIAGRAM OF IDEAL THEORY OF SAND RECLAMATION

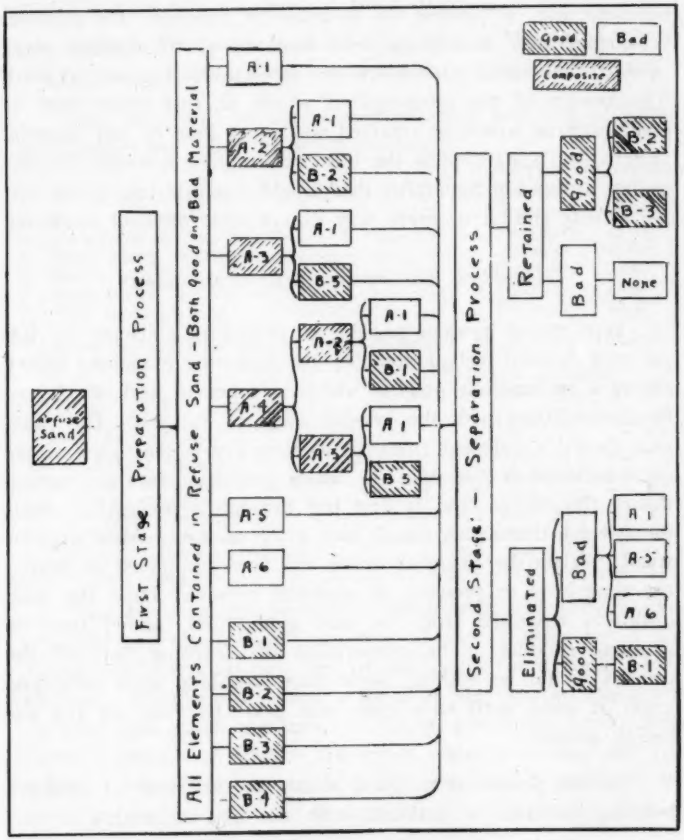


FIG. 2—DIAGRAM OF PRACTICAL THEORY OF SAND RECLAMATION

arate the actual good from the so-called bad material. To stop at this point would not be permissible for the reason that there is a considerable portion of the so-called bad material which has possibilities of rehabilitation. The next step, then, develops into a process of preparation wherein this material is worked over and from here leads to a still further stage of final separation to remove the re-established good material. The results of the ideal system would be that every item of good material would be retained and every item of bad material rejected. To accomplish the ideal reclamation it would be necessary to develop apparatus that would separate two items that are exactly similar in every way except their physical condition.

Practical Theory of Sand Reclaiming

It is not at present possible to obtain an efficiency of 100 per cent in sand reclamation, but the following explained theory shows a reclamation process which is practical and which can be accomplished with the present stage of the art. The practical theory is different from the ideal theory in that some of the good material is lost with the waste product. In the practical theory the refuse sand is first put through a process of treatment which thoroughly cleans each grain of sand, either large or small. When the cleansing action has been completed or during the time it is in process, all material removed from the sand grains is separated from the sand grains and carried away as a waste product. The preparation or cleansing part of the process would be nothing more than scrubbing each individual grain of sand until each grain was perfectly clear of any adhering matter.

In this process some good matter in the form of effective bonding material is removed with the bad material.

In the practical theory, the preparation of the sand or cleaning stage of the process is one which would have to be superinduced by some mechanical action while the separation part of the process could be secured by flotation methods, using either air or water as a means of obtaining the desired

results. The practical methods require that each grain be cleansed of both good and bad material.

Any practical system of reclaiming must be measured according to the degree of cleanliness imparted to the sand grains and the thoroughness of the separation of the process.

Experiments of American Steel Foundries to Determine Most Effective and Most Economical Means of Reclaiming Sand

Tests were run on sand for grain shape and size, and condition under the following seven conditions:

	Average	Screen Size
1. Refuse Sand	Fineness	39.57
2. Plain air separation	Fineness	27.45
3 Centrifugal air scrubbing	Fineness	25.69
4. Plain water separation	Fineness	35.92
5. Water scrubbed	Fineness	33.46
6. Both water and air scrubbed	Fineness	27.26
7. New molding sand	Fineness	34.50

Comparison of Fineness of Sand Reclaimed by Various Methods

	Retained on mesh					
Mesh Size	20	40	60	80	100	Thru 100
No. 1 Refuse Sand	1.2	39.4	37.3	11.4	4.4	6.3
No. 2 Air separated	2.1	65.9	27.4	3.9	0.9	0.1
No. 3 Air scrubbed	1.1	72.9	23.4	2.2	0.4	0.0
No. 4 Water Separated	0.8	39.9	41.4	11.6	5.3	1.0
No. 5 Water scrubbed	2.0	45.0	39.9	8.9	3.0	0.4
No. 6 Water and air scrubbed		69.0	26.6	3.4	.8	.2
No. 7 New sand		50.0	35.1	9.1	4.0	1.8

The air scrubbed and air separated method proved most practical and economical a solution of the problem for it was found that about 70 per cent of the refuse sand could be reclaimed. Plain air or water separation did not put the grains of sand into good condition, a violent scrubbing action being found necessary to remove the fused material coating the sand grains. After the best method was determined attention was given to the development of equipment which would perform the work most satisfactorily and economically.

PART II

Reclaimer for Dry Refuse Sand

Previous to the development of this device, various attempts had been made to reclaim molding sand by separation and by means of air or water flotation, but these methods were only partially successful. In the air or water separation methods, no decided change was wrought in the physical condition of the sand grains. It was also a fact that in addition to being ineffective, the separation methods are not economical, especially when water is used because an abundant supply must be available. It is also necessary to again dry the water separated sand and this is not only expensive but the drying requires careful supervision to preclude the possibility of the reclaimed sand being heated to a temperature which would destroy its usefulness.

As conceived in both the ideal and practical theory the centrifugal air scrubber is based on the idea that reclamation of molding sand is primarily a process of cleansing the grains of sand by removing from their exterior surface all adhering particles of foreign matter.

The principal function of the centrifugal air scrubber is to break up any changing masses or combinations of sand grains and then cleanse them of adhering foreign matter. This method used is called "air scrubbing."

In addition to the scrubbing equipment development the problem of a proper dust arrestor was one of the most important which had to be solved. The centrifugal air scrubber and separator equipment are shown in Figs. 3 and 4.

Explanation of Operation of Centrifugal Sand Scrubbing Device

Sand passing to the scrubbing chamber (1) by means of feed pipe (13) is whirled around the side wall of the chamber by means of the air current set up by the revolving fan blades (5). The sand grain traveling in a circular passage around the walls rubbed clean by the action against the walls and other sand grains gradually rises up to openings (2) passing over

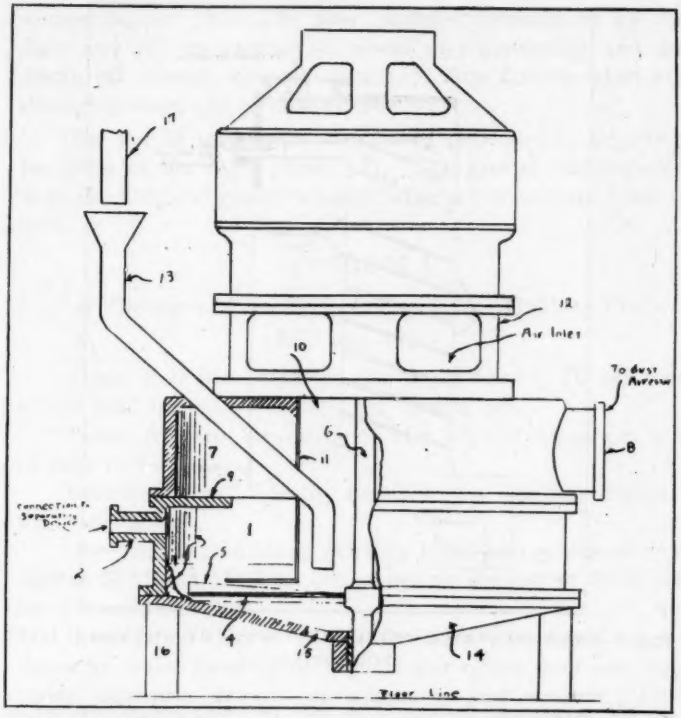


FIG. 3—CENTRIFUGAL SCRUBBING MACHINE OF SAND RECLAMATION PATENTED BY THE AMERICAN STEEL FOUNDRIES

1. Main scrubbing chamber.
2. Outlet for sand to separating device.
3. Wearing ring (replaceable).
4. Fan disc.
5. Fan blades.
6. Driving shaft for disc 4.
7. Auxiliary drum-serving as a dust separating device.
8. Opening for carrying off dust-laden air.
9. Horizontal flange which serves as separating baffle.
10. Opening from drum 7.
11. Pipe to carry air down.
12. Motor stand.
13. Feed pipe.
14. Bowl shaped bottom to accumulate surplus sand.
15. Hole for automatic removal of surplus sand.
16. Stand.

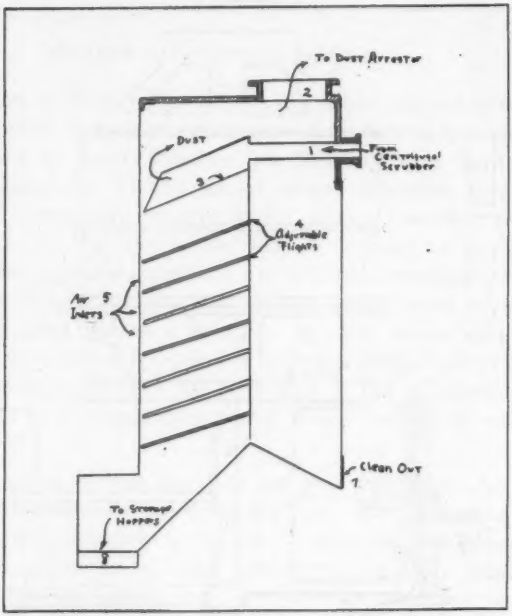


FIG. 4—SAND SEPARATOR ATTACHMENT USED BY AMERICAN STEEL FOUNDRIES

to the separating device. The dust particles are drawn off to chamber (7) and out to dust arrestor through opening (8). Air is carried into chamber (1) through pipe (6) from openings in the motor stand. Surplus sand is automatically removed through opening (15) in the bowl-shaped bottom (14).

Explanation of Operation of Sand Separating Device

The scrubbed sand enters the device through opening (1) and falling onto plate (3)is spread out to width of plate. The stream of sand then falling down in front of flight plates (4) the grains of sand are forced up the inclined plates by the current of air through inlets (5). Starting to roll up the flight plates the heavier sand grains lose their momentum and roll down, falling to bottom of the apparatus and into opening of

storage hopper (8). The finer particles continue on up the flight and fall into section 6, where they accumulate and are drawn off through cleanout door (7). Any dust is taken out through passage (2) to dust arrestor.

The size of sand grains retained is controlled by adjusting the slope of the flight plates (5). The greater the angle of slope the finer the grains retained, when a constant air force is used.

APPENDIX I

Cost of Reclaiming Sand by Centrifugal Air Scrubbing Process. (1920 *and* 1921)

Actual tests have disclosed that approximately 70 per cent of the sand treated is returned for further use.

Power required for machines 14.5 kilowatt hours per ton of sand reclaimed.

Reclaimed sand actually required less bonding material than new sand.

One plant has on books (Oct. 8, 1920) two grades of new sand at $2.55 and $3.07 per ton as against the cost of $1.70 per ton for reclaimed sand.

Investigation showed at this time that cost should be reduced by better handling of gaggers and refuse sand and supplying automatic shakers for screens in dust arrestor. Cost stated includes labor, repairs, and power.

A comparison of costs of reclaiming (March 30, 1921) at three plants is as follows:

	Plant A	Plant B
Tons of Sand Reclaimed (one month)	832 tons	275 tons
Operating hours	474 hours	224.50 hours
Machine hours	666 hours	446.25 hours
Average ton per machine hour	1.25 tons	.616 tons

The aim at B was to produce a sand in every way as a satisfactory substitute for washed dry sand. Comparative cost of new material and reclaimed sand:

	New Molding Sand	New Washed Sand
Cost of new material	$2.65	$3.85
Cost of reclaimed sand	1.15	1.15
Saving per ton	$1.50	$2.70

Plant C reclaimed sand cost $0.88 per ton. This sand was not as clean as at Plants A and B but suited to needs of Plant C.

May 9, 1921. Plant B costs of reclaiming sand was $0.823 per ton against cost of new sand at $2.61 per ton.

APPENDIX II

AMERICAN STEEL FOUNDERS (1921)

Proposed Sand Reclaimer Unit to Be Installed at One Plant

Waste Sand Delivery

(a) Waste sand is transferred from cleaning room and foundry in gondola or dump-cars and sand is dumped onto a bar screen. From this screen, sand is delivered onto a belt conveyor which discharges the sand over a magnetic pulley into a continuous bucket elevator.

(b) Waste sand from knock-out hammers is delivered

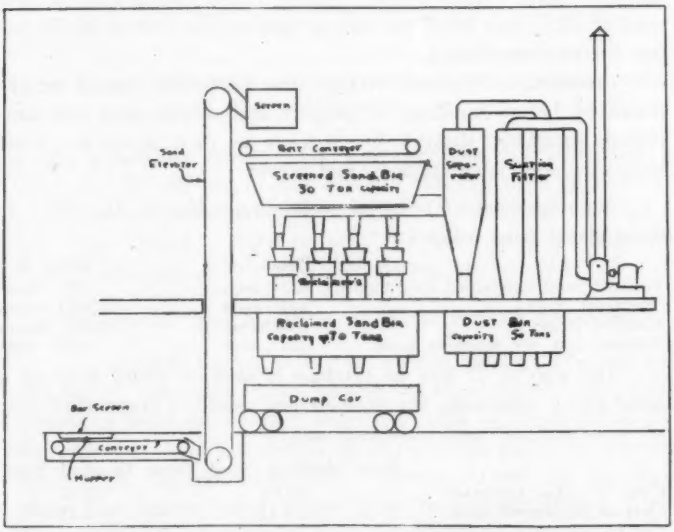


FIG. 5—DIAGRAM OF PROPOSED SAND RECLAIMING INSTALLATION

through a bar screen onto a 24-inch belt conveyor and discharged onto same conveyor leading from waste sand screen of item (a).

Sand Screen

The continuous vertical bucket elevator called for under item (a) discharges into revolving cylindrical screen which discharges onto a belt conveyor, directly over screened sand bin. Over size and tailings are delivered at end of screen into a chute, which discharges into a box setting on reclaimer floor.

Screened Sand Storage

The screened sand is delivered onto a belt conveyor and is discharged into a screened sand storage bin of approximately 30 tons capacity.

Sand Reclaimers

Four sand reclaimers are placed on reclaimer floor or balcony and are fed from the screened sand storage bin by gravity. Reclaimed sand is delivered into bin supported from the underside of new reclaimer floor or balcony. Reclaimed sand bin has a capacity of approximately 70 tons of reclaimed sand.

Refuse and Dust Collectors

The dust and refuse are drawn off from sand reclaimers by means of a 50-inch fan through an adjustable air separator of ample size, where heavy dust is collected, the fine dust being colleged by means of a suction filter of ample size. The free air is then discharged to the atmosphere. The dust collected by air separator and suction filter is discharged into a dust bin, having a capacity of approximately 50 tons.

Loading Out

A car is set alongside of either reclaimed sand bin or dust bin for loading out.

Capacities

Sand Reclaimers.

1 ton reclaimed sand per hour per machine. Four reclaimers equal 4 tons reclaimed sand per hour.

Figuring 70 per cent reclamation, system will handle 5.7 tons of refuse sand per hour. Figuring four tons reclaimed sand per hour, system will separate 1.7 tons of dust per hour. Figuring three reclaimers running, using fourth as a spare, there will be reclaimed in one month 1560 tons. This is based on 20 hours per day and 26 days per month.

Figuring four reclaimers running and a fifth for a spare, there will be reclaimed 2080 tons of old sand per month.

Discussion

H. B. HANLEY.—I think it will be well for us to know definitely if this operation which the paper discusses is just for the purpose of cleaning sand or carrying the sand on to the mixing machines?

R. E. KENNEDY.—Mr. Janssen tells me that the sand is as good as new sand and is used extensively for similar purposes as new clean silica sand.

H. M. LANE.—I have been over all this plant; this equipment is used for taking sand that would go out of the plant and recovering it and put it in shape to use exactly as new sand. The machine is quite complicated. This company has gone further than anybody else has in the reclamation. Each machine takes 10 horsepower. It takes one man's time to keep it going. Only three machines can be run at a time. The essential grinding parts of the machine have a life of from 40 odd to 60 odd actual running hours. That is all included in the cost. It is a thing that would scare lots of people. Yet, the thing shows up in dollars and cents as an actual saving. I believe there are certain other processes that can be developed cheaper than this and possibly sufficiently well; but this plan can be put in effect in steel foundries.

S. H. CLELAND.—It was stated to me that the cost would be prohibitive, but if this method of recovery is available, I think the cost would be reduced.

CHAIRMAN F. L. WOLF.—The cost figures are given on page 755 in the report.

H. M. LANE.—I believe this is a marketable process but the process that will be used in steel foundries largely is not near as complicated. We made very nice castings using nothing but cleaned sand for the facing, and the men said they could almost tell the castings made from our reclaimed sand because they had a better finish than the new sand.

H. B. HANLEY.—There are some certain features in connection with the manipulation of a sand by steel foundries that are very valuable. Mr. Lane has just pointed out the significance of getting better castings from cleaned sand and that, in all probability, is due to the better condition of the sand grain on the sand. We know that if you heat silica grains to a sufficiently high temperature, you transform the grains to different constituency. Now, in regard to the sand at that plant, they must be dealing with that transformed grain; if they are getting a better casting, they are getting it from a definite cause.

Another point I would like to mention is, that I assume, due to the largeness of this corporation, that they have selected only the finest steel sands obtainable for the manufacture of their castings; and I wonder if this process would be so successful when applied to many of our high silica sands inferior to some of the wonderful silica sands of the Middle West.

H. M. LANE.—In running our tests some years ago we started out on a Pennsylvania sand, and others which were a sensitive crushed quartz with angular grains and we found that the microscope told us more than anything else. Each new sand examined under the microscope showed very similar stages and a very large number of incipient cracks. Those were developed into fractures when subjected to heat. With the tidewater sands, essentially round grains, when used the few cracks there were developed into fractures and you got some split grains. You cleaned them out and got what I call

tempered sands. An interesting thing was, after recleaning again and again that you had less waste in each succeeding cleaning.

CHAIRMAN F. L. WOLF.—It seems to me that in this process a great deal has to do with the rounding up of the grain. Do you not think so, Mr. Lane?

H. M. LANE.—That is true. This scrubbing machine that they have throws away from 30 to 40 per cent of sand. The method I was working on is different because I try to avoid that and to conserve more sand. Personally, I do not think it is necessary to go that far in cleaning for ordinary steel foundry practice; a much more simple process can be worked in and made use of very nicely. In fact, I think that same thing can be worked for an iron sand. We clean a very large amount of core sand by direct process and make molding sand out of it and turn it back into the business; and it is nothing in the world but cleaned core sand bonded with clay and made into molding sand.

A MEMBER.—How do you clean the sand you talk about?

H. M. LANE.—We first put it through some light scrubbing process; sometimes we use a barrel; sometimes we run it through two or three sets of rolls to crush up the grain and then put into an opening with plates turned in so that it falls from one plate to the other from a height of from one to two or three inches. If you put it through a scrubbing process you will sacrifice all of your bond. Then we take that product and simply bond it with clay in a continuous roller mill. All you want to do is to get your grains cleaned and then properly covered with the bonding material. A good many steel sands you can wash better and easier and cheaper. Then, if you get a suitable bond system in which you can get a sand and leave it until it works down by gravity to its proper condition; then you can work that in with dry material and get away with it all right.

Now, that brings up a little point of interest. In this recovery proposition, we were trying to standardize our means of production and the question came, how were we going to

keep our moisture right. Here is sand coming from a bin with unknown moisture content. If we use that sand right along where will we land? I discovered that any sand of a given grain size having a low moisture content, if left in the bin, under ordinary conditions would assume a certain moisture content. Michigan City sand, if left there any time would contain five per cent moisture. Any Rochester bank sand should be around eight or nine per cent, and Ottawa silica would be around 2½ to 2.6 per cent and so on. So then we devised the method of always taking our sand from the face of the bin so as not to get it mixed up.

The Significance of the Screen Test of Molding Sands

By H. A. SCHWARTZ, Cleveland

Among the tests frequently applied to define the quality of a given sand is the so-called screen test which indicates the relative amounts of the sand passing through one and retained in the next of a series of screens having mesh sizes of more or less arbitrary gradation. The test is cheaply made and does constitute a fairly useful method of comparing two sands supposed to be identical. Presumably it furnishes information as to the porosity of the sand and as to the smoothness of surface of a mold made therefrom. Moreover, there is a general opinion that perfection of mold surface can be had only at the expense of poor venting properties and *vice versa*.

Two facts may easily be overlooked in the interpretation of any such test for practical purposes. First, the porosity of a mixture of grains of various sizes is not the weighted mean of the porosities of the several constituent grain sizes. Second, the porosity of a dry sand is far different from that of the same sand moistened to the degree encountered in foundry practice.

A further complicating factor is that as yet there is no orderly and logical selection as to the fineness of sieves used for the purpose of testing sands and hence there is a possibilty of going far astray in an attempt to corrolate data based on different selections of sieves.

This paper has been prepared with a view to rendering available certain data gathered by the writer in 1910 in a preliminary survey of these aspects of the subject. It must be understood that no presumption to completeness and finality is set up. It is hoped that certain sources of error in the applications of screen tests, not entirely obvious to the foundry man, may be pointed out.

Molding sands consist of rounded quartz pebbles of small

size more or less coated with clay. Some idea of the complexity of any mathematical interpretation of porosity in terms of grain size may be gained from a mathematical investigation as to some of the simpler groupings of spheres in space. The simplest symmetrical grouping is that where eight spheres of equal size are so arranged that their centers are situated at the corners of a cube. In that case if d represents the diameter of the sphere, the sphere centers are separated by distance d and the spheres themselves represent $\frac{\pi}{6}$ times the total volume of the mass.

The next simplest arrangement is one in which the centers of the spheres occupy the six corners of a right equilateral prism. In that case the sphere centers are also a distance d apart, but the spheres now occupy $\frac{\pi}{3\sqrt{3}} = \frac{\pi}{5.19}$ times the total volume. In other words, the spheres are more compact than in the case of the cubic arrangement.

The remaining symmetrical arrangement is one where the centers of adjacent spheres are at the points of a regular octahedron whose edges have a length d in which case the spheres occupy $\frac{\pi}{3\sqrt{2}} = \frac{\pi}{4.23}$ of the total volume a still closer pack than either of the preceding. This spacing automatically includes two tetrahedra for each octahedron.

Still another arrangement is the tetrahedral in which the centers of the spheres are at the vertices of regular tetrahedra. The volume of the sphere then is $\frac{\pi}{3\sqrt{2}} = \frac{\pi}{4.23}$ of the total volume identical with the octahedral pack. Also each pair of tetrahedra is accompanied by an octahedron. That is, the pack is identical with the preceding except in orientation as a whole.

Other less dense and unsymmetrical packings can be imagined. It is obvious that a mass of spheres free to move or rammed into place in a container having dimensions a multiple of their diameters will arrange themselves in the densest pack possible—the tetrahedral, octahedral—and that the density of packing of uniform sized spheres is then independent of the diameter.

This, however, does not mean that the porosity of all the systems, in the sense of resistance to air flow, will be the same irrespective of the diameter chosen.

The resistance of a passage to the flow of a gas or liquid fluid is in general directly proportional to its length and peri-

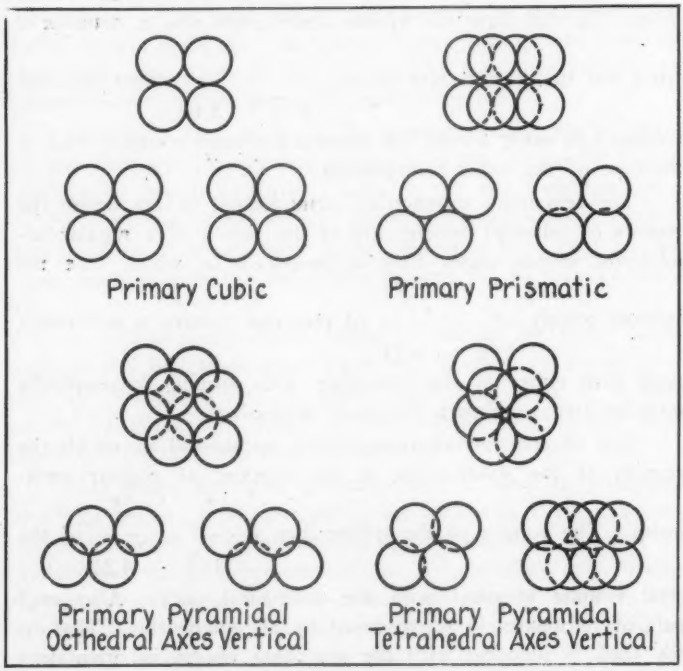


FIG. 1—PRIMARY SYSTEM OF GRAIN ARRANGEMENT

meter and inversely as its area. Per unit length therefore it is proportional to the perimeter divided by the area of the passage. The reciprocal of this figure is a geometric constant known as the hydraulic radius.

In any given pack of uniform spheres the area of cross section varies as the square of the diameter chosen while the mean perimeter varies as the diameter; the frictional resistance per unit length to fluid flow thus is inversely as the diameter of the spheres and the sand's perviousness to gas is inversely in this proportion. This is based on the supposition that the gas does not frequently have its direction reversed by having to flow around obstacles.

If this condition does exist, the number of changes of direction per unit length should be a straight line function of the size of sphere; hence the resistance to flow would again be an inverse function of the grain size in a given pack. It would be simple, but of doubtful utility, to calculate the hydraulic radius for the form of passage in the three packs and so show their relative resistance to flow.

We may turn now to the more complex systems of spheres varing in size. For our present purpose they may be considered primarily as modifications of the previous systems by additions of other spheres.

For instance, if a circle be drawn externally tangent to three equal circles tangent to each other, and if d be the diameter of the equal circles d, the diameter of the fourth circle will be $\left(\frac{2}{3}-\sqrt{3}-1\right)d$ or $d_1=.154d$. Similarly for a circle tangent to four equal circles tangent to each other the diameter d_2 will be $(\sqrt{2}-1)d$ or $d_2=.414d$.

Any sphere having a diameter larger than d_1 can not pass outside any octahedron or tetrahedron in which it finds itself and similarly any sphere larger in diameter than d_2 can not pass the sides of the cubic or triangular prism elements of that pack.

The sphere tangent to six spheres of diameter d arranged

in the octahedral system will also have a diameter of d_2, the problems being identical.

This is the largest sphere which can be packed into the center of an octahedron without preventing the contact of the six spheres of the primary system. Any sphere whose diameter is greater than d, and less than d_2 will fit loosely within

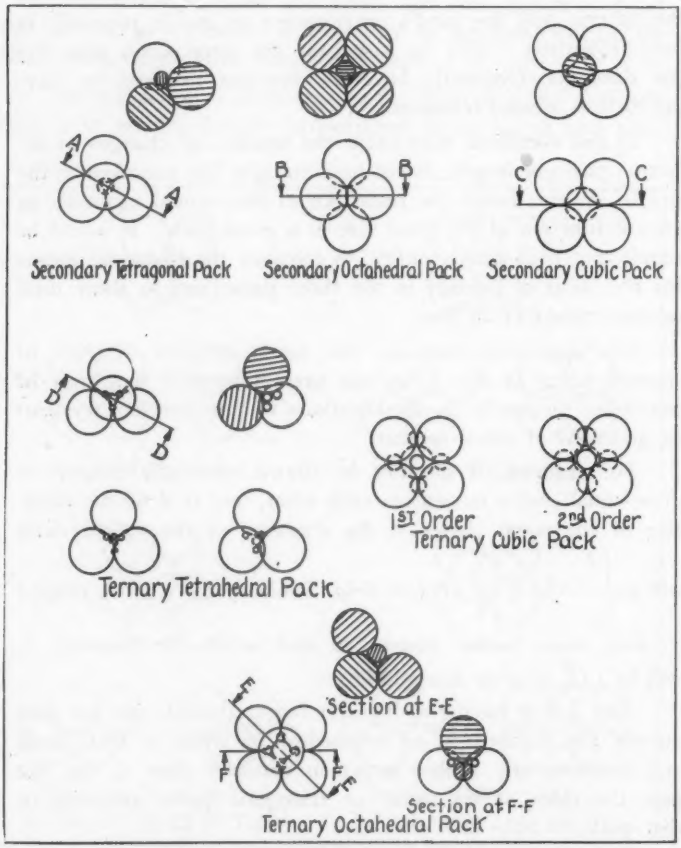


FIG. 2—SECONDARY AND TERNARY SYSTEMS

the octahedron and any spheres smaller than d, sift down through the primary structure of larger spheres.

The sphere tangent to the spheres of the tetrahedral system has a diameter $d_3 = (\frac{1}{4}\sqrt{6}-\frac{1}{2})$ or $d_3 = .220d$.

What has been said of spheres having diameters of d_1 and d_2 in the octahedral arrangement applies to diameters of d_1 and d_3 in the tetrahedral.

We can see that in the pyramidal pack consisting of one octahedron and two tetrahedrons in each unit (i.e. per each primary sphere of diameter d) we may add one sphere of diameter d_2 and two of diameter d_3. This combination is the densest possible, using only one extra sphere in each regular polyhedron. The density of the pack has been increased from $\frac{\pi}{4.23}$ of the total volume solid to $\frac{\pi}{3.87}$ or by 9.2 per cent of its original value.

The resistance to flow would be increased much more rapidly, for the interposition of the extra spheres would enormously decrease the mean area of the passages and increase their perimeter. If too many of the smaller sizes of spheres be added or they be too large the whole structure is loosened up by their wedging action on the primary structure. We might readily proceed to calculate still other smaller spheres to fit the various interstices of the system of primary and secondary spheres already calculated. We should then get an endless series of different numbers of various sizes of spheres which would give the maximum density. Such a series being calculated, any change in relative numbers and dimensions would produce a loosening up of the structure either by leaving voids if the small ones were too small or too few or by wedging if they be too large.

The mix just calculated for the primary and secondary series of the pyramidal system corresponds by volume and

hence by weight to the following:

Number of spheres	Diameter	Volume or Weight	Per cent of total
1	d	$1.000\frac{\pi d^3}{6}$	91.58
1	$.414d$	$.071\frac{\pi d^3}{6}$	6.50
2	$.22\ d$	$.021\frac{\pi d^3}{6}$	1.92
4		$1.092\frac{\pi d^3}{6}$	100.00

With sufficient patience and mathematics we could similarly calculate the percentage composition of a series of any desired degree of complexity.

A further complication may arise where the spheres of the secondary series are of such dimensions as to rearrange the geometric system of the primary pack. The sphere tangent to four spheres in the cubic pack has a diameter of $.732d = d_4$ and therefore the cubic system will accommodate one sphere of this diameter for every sphere of diameter d.

The density of the pack is increased 39.2 per cent to $\frac{\pi}{4.31}$ a density but little less than that of the pyramidal primary system.

If to the latter system spheres larger in diameter than d_2 or d_3 be added the pack would be loosened, if, however, the number and size were as indicated above the pack would become primary and secondary cubical with a possible increase in density.

Thus it is indicated, for example, that a mix of equal numbers of spheres of diameters d and d_4 has the same density although not necessarily the same resistance to flow as one all composed of diameter d or d_4, which is not necessarily obvious at first glance.

We have so far dealt with a primary series and a secondary series composed of spheres of smaller diameter than

the primary. The ternary series can be readily studied. For example in the pyramidal pack we could introduce at each triangular face a ball of diameter d, without touching the secondary spheres of diameter d_2 and d_3. This would give seven spheres of diameter d, for each sphere of diameter d and the pack would become:

Number of spheres	Diameter	Volume or Weight	Per cent of total
1	d	$1.000\frac{\pi d^3}{6}$	89.5
1	$.414d$	$.071\frac{\pi d^3}{6}$	6.3
2	$.22\ d$	$.021\frac{\pi d^3}{6}$	1.9
7	$.154d$	$.026\frac{\pi d^3}{6}$	2.3
—		$1.118\frac{\pi d^3}{6}$	100.0

The pack is increased in density 11.8 per cent over that of the primary but of course much more in imperviousness as each secondary and ternary sphere greatly decreases the cross section and increases the surface of the passages through which gas can flow.

In the cubic pack a sphere of diameter d_2 can not be introduced as a ternary sphere the maximum diameter which will not touch the secondary series being $.268d$.

Another pack, however, is possible in which the ternary spheres have a diameter $.414d$ and the secondary sphere touches these and not the primary. The secondary sphere then has a diameter $.586d$.

The tremendous complexity of calculating resistance to flow from the dimensions of such complex structures is obvious.

If we added a large number of large spheres we would disarrange the primary series by substituting a new primary system corresponding to the larger spheres. Without attempting a formal mathematical solution it will be evident by inspection

that if we buried a larger sphere in a mass of relatively quite small ones, it would with but an insignificant disturbance of a few small spheres near its surface render impervious a large volume of the mass it occupies.

A further instance is the second order cubic pack already described. We need speculate no farther. Enough has been said to indicate that the design of a suitably graded series of screens even for a single sand and the interpretation of its result into terms of porosity or venting properties is inherently too complex to be considered an experimental possibility. The matter is further complicated by the consideration that the natural sands are not perfectly spherical and consist of a uniform gradation of sizes and not of groups differing in size by sharp limits.

It can be seen that an absolutely even size of grain gives the most open sand. Such sands do not exist in nature and while it may be assumed that the nearer any natural sand is to even grain size the more open it will be, even this generalization may fail where the mixture of sizes is very complex.

Experimental Data

Fortunately we are not dependent on sieve tests to determine the resistance of sand to the passage of air or its perviousness. The problem is capable of simple and direct observation by determining the rate of flow of air through the sand at some selected pressure.

The data may be expressed either in volume of air per unit of time or in time per unit volume. The two are reciprocally related and the latter form is a more direct measure of the property of interest in the foundry than the former.

The form of test is by no means original with the author. As conducted by him it consisted of ramming into the tube *A*, shown in Fig. 3, three successive measured lots of sand from the measure *B*, each filling the tube 1 inch deep before ramming. Each layer was settled in place by three blows of a weight of ¼ pound falling one inch, by means of the rammer *C*. The time was observed for 250 cubic centimeters of water

to flow out of the aspirator bottle *D* under an constant fixed arbitrary head of about 3½ inches.

Pains must be taken to avoid leaks and also to make sure that the water level within the tube in the aspirator bottle is at the bottom of the tube and bubbles flowing before beginning the experiment.

The apparatus was used primarily for the direct measure-

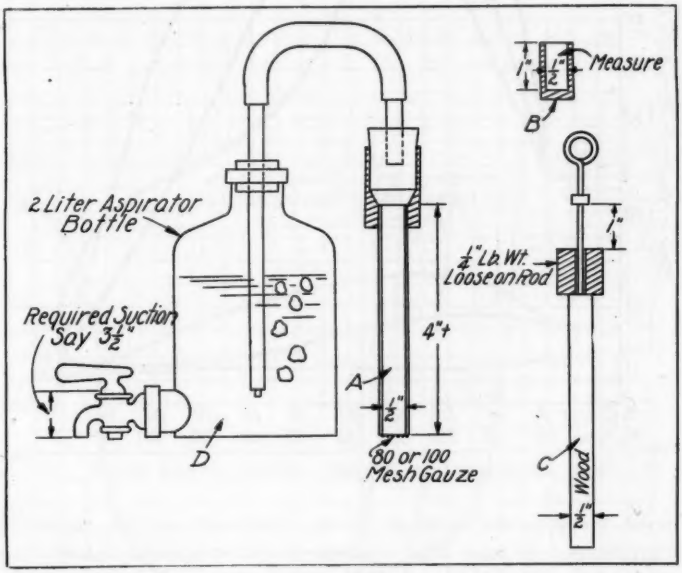


FIG. 3—APPARATUS USED FOR TESTING RESISTANCE OF SAND TO AIR

ment of the resistance to flow of natural and used molding sands. For purposes of experiment a given sand was separated into fractions by screening through 20, 40, 60, 80 and 100 mesh sieves. The various fractions were then combined in various definite properties two at a time, and the resistance to flow of air of the binary mixtures determined.

The data, on dry sands are plotted in Fig. 4. It should be noted that except by accident the resistance of the mixture is

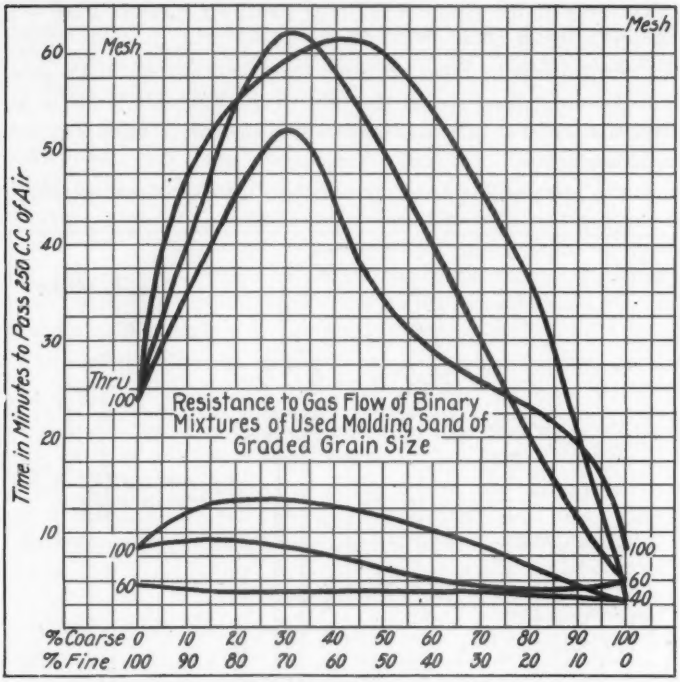


FIG. 4—RESISTANCE OF DRY SANDS TO GAS FLOW

never the weighted average of the resistances of the separate ingredients. It may have maximum and minimum values.

A simple experiment will show that if 95 cubic centimeters of dry sand be mixed with 5 cubic centimeters of water the resulting mixture can not be put into a 100-cubic centimeter cylinder. The porosity of the sand has been increased by adding the water. A corresponding effect on resistance to flow of air is to be expected.

In Fig. 5 is shown graphically the effect of moisture content upon sands of uniform grain size. It is worthy of note that the moisture for maximum venting properties is not far different for sands differing widely in grain size. The author

has not attempted to examine the mechanism of this effect of moisture in detail; it may be due either to an increase in the grain size, each grain being increased in radius by the thickness of the film of water at its surface or to the holding together by surface tension of many small damp grains to form a single large one. The phenomenon occurs to a limited extent in grains of pure silica so it is not solely due to the colloidal clay coating.

Binary mixtures of sands of different grain size when damp behave somewhat similarly to the dry mixtures although

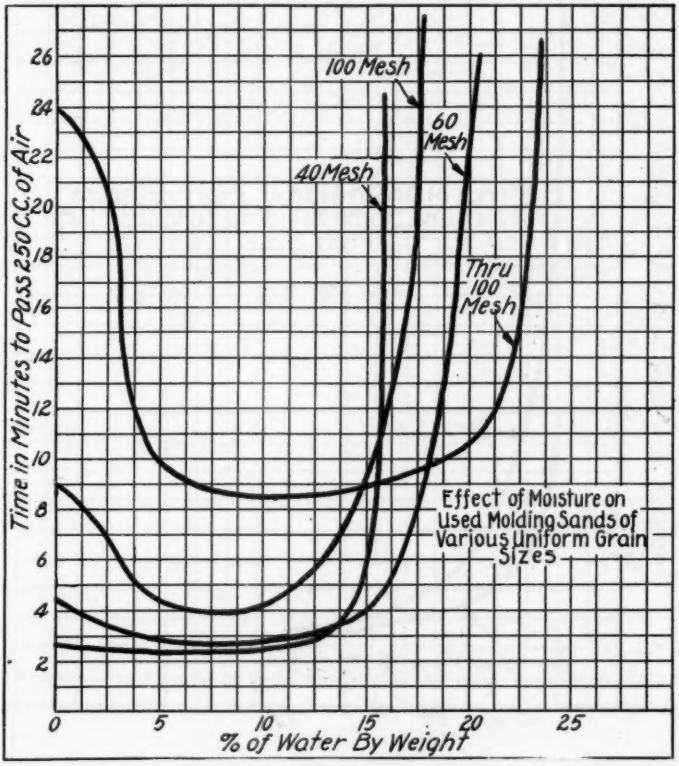


FIG. 5—EFFECT OF MOISTURE ON USED SAND

the changes are not identical and usually less marked.

In Fig. 6 the resistance to flow through uniform grained fractures is plotted against grain size, a separate graph being shown for dry sand and for sand of 10 per cent moisture corresponding approximately to the point of maximum perviousness.

If ternary mixtures—mixtures of three grain sizes—are used, complex relationships occur. Any point within the triangle of Fig. 7 may represent the composition, by per cent,

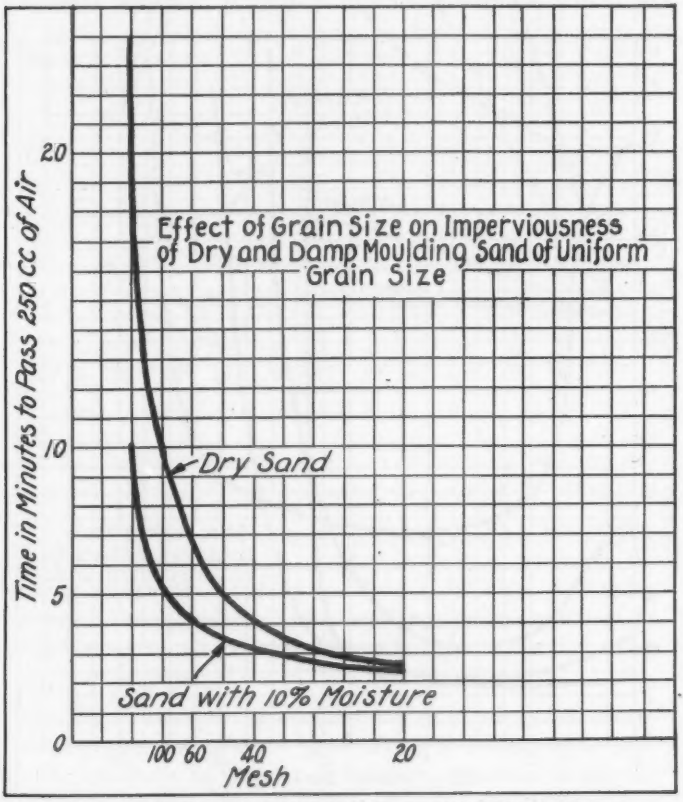

Effect of Grain Size on Imperviousness of Dry and Damp Moulding Sand of Uniform Grain Size
Time in Minutes to Pass 250 cc of Air
20
10
5
0
Dry Sand
Sand with 10% Moisture
100 60 40 20
Mesh

FIG. 6—EFFECT OF GRAIN SIZE ON IMPERVIOUSNESS

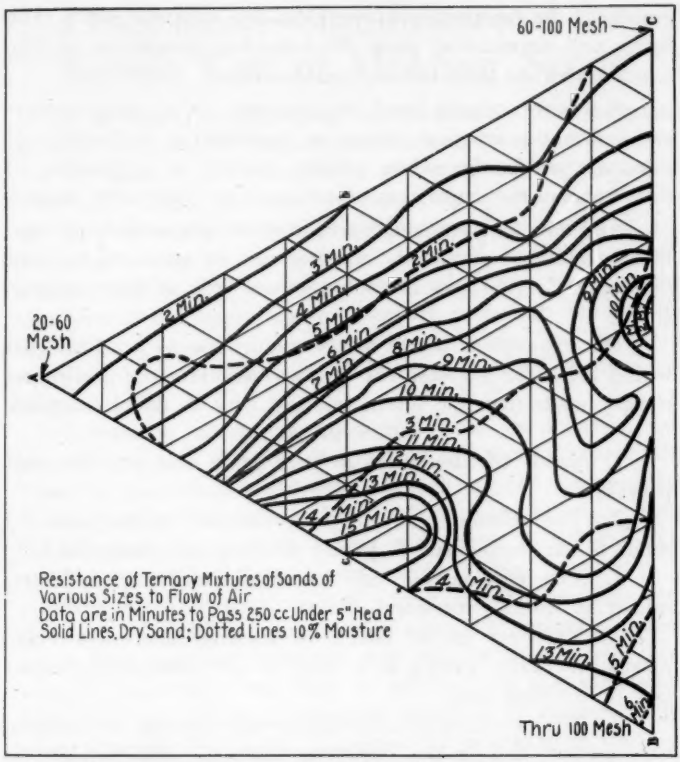


FIG. 7—RESISTANCE OF TERNARY MIXTURES TO AIR FLOW

of a sand consisting of three grain sizes. The corners represent mixtures 100 per cent of a given size (one corner for each of the three sizes chosen). The binary mixtures are along the sides of the triangle and the ternary mixtures within it, the relative amounts of the three ingredients being in proportion to the distance of the point marking the mixture, from the three sides. The resistance to flow, in time per unit volume is shown by contour lines, all points in a given line having the same resistance. Lines are plotted for both dry and damp sand.

The data are not directly comparable with the binary

graphs as the determinations were on two different sands. The figure will nevertheless show the exceeding complexity of any relation between sieve test and perviousness.

A note of caution should be inserted. It is clearly understood that the fractions taken as representing uniformity of grain are within themselves actually present in a gradation of sizes between the dimensions of two adjacent successive screens.

Had time and equipment permitted the preparation of fractions consisting of exactly equal grains in each fraction the inflections in the curves would become still further accentuated.

The experiment would be interesting but no practical gain would arise for the test for perviousness is more easily and cheaply made than the screen test and may be directly applied.

Conclusions

1. Sands of absolutely uniform grain size are the most pervious.

2. The relation between grain size and perviousness of sands is too complicated to permit drawing any conclusions.

3. The perviousness can be readily and cheaply determined by direct experiment.

4. The sieve test of sand is of academic interest only and means practically nothing in a study of the commercial properties of molding sand.

5. The perviousness of molding sand depends on its moisture content and in the beginning increases with increase in moisture.

Discussion—Significance of the Screen Test of Molding Sands

H. B. HANLEY.—Referring to conclusion No. 2 in the paper by Mr. Schwartz, the relation between grain size and perviousness of sands is too complicated to permit drawing any conclusions; I might say that our committee on standard tests has gone into this matter thoroughly and we find this relationship is not so complicated. We find it rather simple, and I think you will all appreciate this when you get the recommendations regarding the standard procedure for making a fineness test on molding sands for I believe you can very easily apply the information and will find it to be of great practical value.

Concerning conclusion number 3; the perviousness can be readily and cheaply determined by direct experiment. There is no question about that. We do not call the openness of the sand perviousness. We have tried to adopt a name for the standard test work which will appeal to the industry.

Number 4 has already been touched upon.

Number 5 is worth taking a few minutes on; the perviousness of molding sand depends upon its moisture content and in the beginning increases with the increase in moisture. We all know very well that if we load up the sand with water and get it into a condition where it is unquestionably heavy, that we then have a question of permeability which is different from that which we would obtain in a properly tempered sand that has been properly worked over and allowed to stand for a reasonable amount of time. After going through practically all the literature published on molding sands and being quite conversant with it, I noted some two years ago that no investigations had been carried out that were at all conclusive and which showed the proper amount of water to be added to molding sands. When I say 'the proper amount,' I mean, the amount of water which is essential for very good successful work, and that varies with the different sands. It was clearly shown in a resume of the literature that every author was inclined to slight the significance

of proper addition of water, and then the subsequent treatment of the sand with a view to bringing about uniform temper. The manufacturers of the sand handling equipment came very close to a solution of that problem but they have conditions that at times are not very satisfactory. So that what you get in a large shop is approximately 5 per cent moisture in one heap, six in another, and perhaps four in another; yet, over in the other end of the shop you have found eight per cent. It is not stating anything unusual when I tell you that there is a difference in the castings. Now, that is the effect of water. So Mr. Schwartz very thoughtfully emphasizes the point that that particular condition has an effect upon the perviousness of molding sand, and it is a good point because it is a point that certainly needs much greater investigation and discussion than we have had heretofore. It is clear, I think, to all of you just how that water can do the harm. It swells up the clay to begin with. For instance if you take and mix clay and water in a suitable container, you reach a stage where the clay is taking up 10 or 12 per cent of water and it feels relatively dry. You carry it further and it becomes wet and shows plasticity. You carry it right to the point of saturation with the water and you will find that the condition of the mass is practically impermeable. That comes to my mind in an effort to furnish you with an example of the extreme influence of addition of water.

H. M. LANE.—In regard to sand tests; the effect of grain size shows more in nonferrous work than in ferrous work. A great many years ago I had to cast or try to cast an alloy with 1.3 per cent phosphorus. We made a one inch core of Michigan City sand; a dry sand core. The metal went through the core and filled the vent. We were first using a Michigan City sand, about 60 per cent of which passes through between 40 and 50 mesh sieves. We found a sand in another location, 80 per cent of it passed a 100 mesh sieve and only 10 per cent passed a 150 mesh sieve. In other words, we took that sand that uniformly went between 100 and 50 mesh sieve, made a core of it and it gave a successful core. Now, the same thing we found out in molding sands;

that the grain size played an important part and grain size could only by obtained by sieve test.

Now, coming back to moisture content, there have been plants in this country that have run those tests for twenty years. One company devised an electric device for it and used it every day in the shop. We have about two or three foundries where we determine the moisture. We found that it would vary between 2 per cent and 0.85 per cent in washed silica sand for steel foundry work and up to nearly 11 per cent in other sand.

CHAIRMAN F. L. WOLF.—We have found that same condition exists as Mr. Lane found and we would be lost in our work without the fineness test. We find that point is very important. We have found that by careful following up the sieve test and a test which we have devised for determining permeability, etc., we have cut our core losses, which were 40 per cent two years ago to within 10 per cent. Two years ago we had in the neighborhood of sixty-five girls making cores for valve work; today we have 17 girls, doing more work than the 65; and our losses have dropped to less than 10 per cent. It is done by making use of tests similar to those on which Mr. Hanley's committee is working and by means of proper supervision.

H. M. LANE.—What causes that 10 per cent?

CHAIRMAN F. L. WOLF.—It is due to carelessness in handling, usually by green help.

H. M. LANE.—At the Wilson Foundry we ran a series of tests that was peculiar, to determine the best method and my memory is that we kept the whole loss under 3 per cent.

CHAIRMAN F. L. WOLF.—I believe that it is possible with labor conditions as they are and considering the class of cores we make, that in handling is where the biggest loss comes. If we could eliminate the loss due to careless handling we can trace it up to some carelessness.

record of our losses and when we see a peak condition we could run with two or three per cent loss. We keep a

S. H. CLELAND.—About the importance of water content of molding sand, I have a report before me in which

the moisture content of heap sand and facing sand is given, running for the period of a week with the exception of Tuesday, in which the figures are: For Monday, 3.7; Wednesday, 3.7; Thursday, 3.6; Friday, 3.7; Saturday, 3.8; that is for heap sand. Number 1 facing: Monday, 3.6; Wednesday, 3.7; Thursday, 3.6; Friday, 3.7; Saturday, 3.8. Number 3 facing has some uniformity; and it was stated to me by the works manager that if that percentage varied more than one per cent that works manager would lose his job. I became interested in it because I understood that they had a rapid method of determining moisture, taking up two minutes, I understood; but I was not able to determine just what method they did use, but I hope to later on.

CHAIRMAN F. L. WOLF.—I imagine that is a test something like that used by G. K. Elliott at the Lunkenheimer Co.

R. F. HARRINGTON.—I have some correspondence that rather indicates to me that the General Electric had an interesting problem on that condition. May be Mr. Sampson could tell us.

J. M. SAMPSON.—The firm I received the information from had high speed automatic machines working on castings, some of which would show up too hard. Careful control of the moisture content of the molding sand reduced these hard castings. There was no chemical control, so far as analysis of the metal, that would solve the problem at all. But what success has been obtained was from very careful control of moisture content.

H. B. HANLEY.—The representative of the General Electric Company seems to have put that question of moisture content into the best expression in a few words; that if we pay the proper attention to moisture content we can realize a saving on castings quicker than by any other single test that you could adopt immediately, because it is clear to anyone who has followed the foundry problem long enough that an occasional defective casting will spring from a little error. I would like to hear more advisory information on the ques-

tion of what is regarded as a proper amount of moisture for different classes of sands, providing any and all members present would be good enough to give the information. Mr. Cleland quoted some figures showing 3.7 moisture on the heap sand.

J. M. SAMPSON.—Around 6 per cent evenly distributed is what we have been working with.

S. H. CLELAND.—Is not the amount of moisture required by each sand, dependent upon the amount of clay? A clay requires a proper amount of moisture to develop its maximum bond and, on that account, would not each sand require a different amount of moisture and would not the proper thing to do be to find out by a certain test just what the particular amount of moisture in each sand content with its clay content?

A Study of the Change in Grain Size of Silica Sand Through Constant Addition of Clay

By R. J. Doty, Milwaukee

To those foundrymen specializing in small steel castings, facing sand is of vital importance. This is particularly true where small steel castings are produced in green sand. Every man responsible for the production of such castings sooner or later has certain ideas as to what will make facing better or worse.

A common theory, and one usually accepted as fact, is that the constant addition of clay to sand where heap sand is used as a part of the batch, causes the facing to become closer or finer. The writer believed this, too, until confronted by facts which indicated that this theory is not true in all cases.

One morning, while examining some castings, he was seized with the idea that a certain combination would produce cleaner castings. Several batches of sand were prepared, and the castings made in this sand were examined carefully. The results were so gratifying that after repeating the test several times the mixture was adopted as standard for the shop.

It must be admitted that this course was decided upon with some misgiving, for the theory already mentioned was considered true; but he believed that nothing serious could happen without some warning. In addition, the shop was protected by the practice of testing the facing sand for permeability, grain size, green bonded strength, and moisture each morning and afternoon.

At the end of a week our sand was a little more permeable. At the end of a month this was more noticeable. At the end of six months, and again at the end of the year, it was still more open.

For a year we had been using heap sand over and over in our facing, adding clay to it each time it went through the mill. At the start we had been afraid it would soon become too close, yet at the end of a year it was more open. To become more open, it would have to become coarser first; and to become coarser, it would act contrary to the old belief that the constant addition of clay would make it finer.

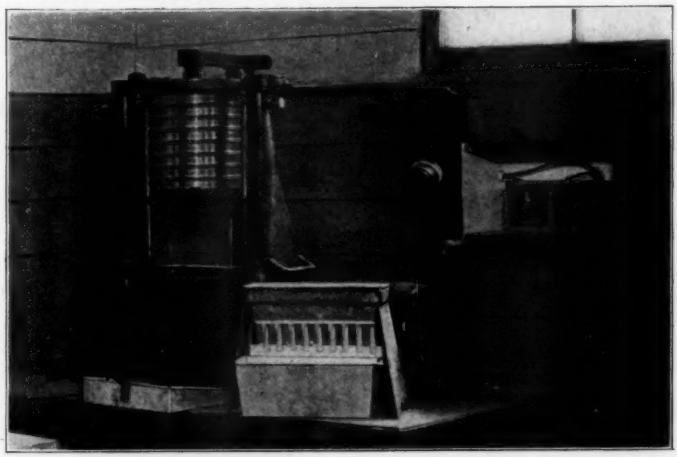


FIG. 1—APPARATUS USED FOR TESTING SILICA SAND

At this point it seemed a study of the effect upon the grain size of silica sand through the constant addition of fire clay would be worth while. The writer decided to carry on this investigation, using every precaution to guard against error and to eliminate so far as possible all uncertainties.

A quantity of washed and dried silica sand was put into a bin and kept for this work. This sand was transferred from the unloading point to this bin by wheelbarrows, and a sample taken from each barrow. These samples were combined and put through the sample splitter shown at the right in Fig. 1.

Using the nest of standard sieves and the ro-tap shown in

Fig. 1, its average grain size was found to be 0.01283 inch. In the same manner, fire clay was stored, sampled, and tested. Its grain size was found to be 0.01144 inch.

Care Used in Investigation

To guard against the introduction of anything into the sample other than the sand and clay just mentioned, the following practice was adopted and followed during the entire test.

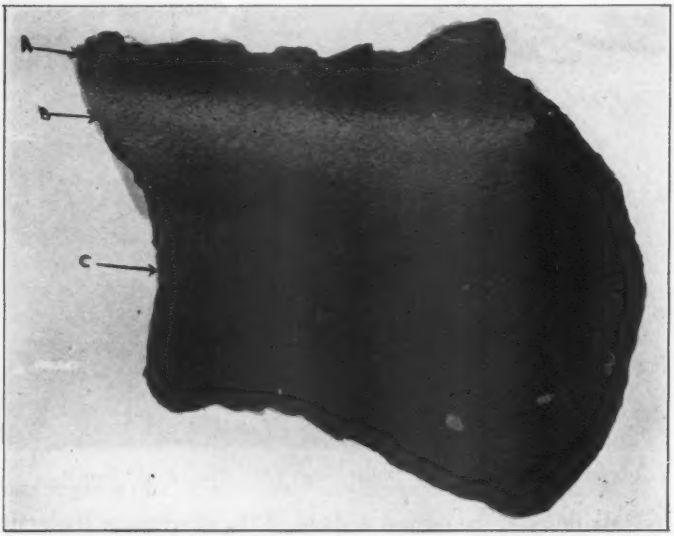


FIG. 2—SAMPLE OF SAND TAKEN FROM POURED CASTING

Molds were made on floor or bench, but no sand other than the experimental facing was used in any mold, i.e., molds were rammed of facing only, no heap sand being used. Where possible, patterns requiring no cores were used; and where cores had to be used, they were small and of such nature as to remain in the casting.

The writer or a molding foreman supervised the pouring of every mold to make sure that nothing was thrown on the mold to cover hot metal in heads and gates. A large steel plate

was placed in a convenient part of the shop. This plate was carefully cleaned each time so that no foreign matter entered the sand from it. The castings were pulled out to one side of the plate with the usual amount of sand adhering to them. The sand from this plate was shovelled into wheelbarrows, previously cleaned ,and covered with a clean sack. This sand was locked up until the next day for use in the next batch.

When the castings were cold, a sample from the sand adhering to them was taken. Fig. 2 illustrates a typical case: *A* is the fused portion which adjoins the casting; *B* is that portion of the sand near the casting, the bond of which is destroyed by the casting temperature; *C* is that layer of sand near enough to be baked, but not near enough to be burned.

Our reason for this step will be evident. Facing from the mill might, upon test, show a grain size apparently greater than the original sand. The same facing after exposure to casting temperature might have its grains broken down by that temperature, in which case it would be finer than when it came from the mill, and perhaps finer than the original sand. In actual practice much of this sand would get into our heaps and would affect them. Therefore we tested for grain size taking a sample from the mill and a sample of the same sand from *B* after casting and cooling.

Similar Mixing Followed

Each batch was mixed in the same mill, one of the heavy muller type, and all batches were milled for the same length of time. Before introducing the material into the mill, all parts were cleaned. The plows, sides, and faces of mullers were cleaned with a scraper followed by a broom while the machine was in operation. By a thorough use of shovel and broom, all loose material then was removed from the pan. The plows were adjusted carefully by the writer, and their setting measured so that as wear developed, they could be readjusted, thus maintaining as closely as possible the same mechanical turning over of the batch through the entire experiment.

The idea was to start with all new sand and clay, for this, after a time, would become heap sand, the contents of which

were known to us. After producing this heap sand, we could use it in conjunction with new sand and clay exactly as we were doing in every day practice during which we had noted an increase in the openness.

This practice, if followed, would of necessity show what effect the constant addition of clay to sand would have on the openness of our facing, for since no material other than clay was added, the results found, whatever they might be, could be due to clay only.

The writer believes he is justified in making this statement, for the only other factor which might enter would be the

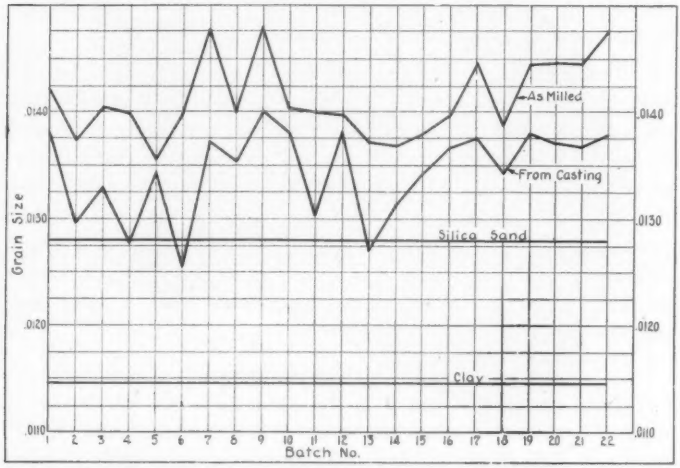


FIG. 3—CHART SHOWS HOW ADDITION OF CLAY AFFECTS GRAIN SIZE

effect of casting temperature upon the sand and clay, and this uncertainty had been guarded against by sampling the burned sand.

The first batch required a heavy clay addition to provide sufficient bond. The next four batches contained less clay and varied somewhat in the clay content, as they did in the addition of new sand.

Of course, the reason for this is that some sand was lost in filling the molds, in shaking out and through adherence to

the castings. The standard batch was ten 12-quart pails, so in the first seven batches we used what sand was saved, adding sufficient new sand to bring the batch up to standard size. After batch seven we saw that it would be possible to recover seven pails from each batch, so we adopted the standard mixture of:

7 pails (84 quarts) used sand
3 pails (36 quarts) new sand
5 quarts fire clay

and varied from that in but the single case of Batch 14, where we lost four pails instead of three.

Chart the Results

The writer feels that the results obtained can best and most briefly be described if done graphically, so attention is directed to the chart in Fig. 3. The figures at the left indicate the grain size expressed in inches, while those at the bottom represent the batches. The lower horizontal line shows the average grain size of the clay used, while the upper represents that of the silica sand. The lower irregular line represents the grain size of the sand taken from *B*, Fig. 2. This indicates that this sand, though brought to a high temperature, where it might be expected to be broken up, is coarser than the original silica sand.

The upper irregular line represents the grain size of our facing, and is that with which we are most concerned. It indicates clearly that in spite of occasional recessions, the tendency is not to become finer, but, in fact, to become distinctly coarser after batch No. 14. A question might naturally arise regarding the tendency to become finer from batch No. 9 to batch No. 14. It is to be regretted that I did not make sieve tests of that particular silica sand which was added to each batch under investigation. If that had been done, there might be offered a satisfactory explanation of the temporary recession mentioned. If the tendency of the facing to reduce in grain size throughout the preparation of a few batches was not due to a corresponding reduction in the grain size of the pure sand, I can offer no explanation of the drop in the curve. The significant thing is that the curve shows no general tendency to

fall, despite the continued additions of clay. In this connection it will be observed that the curve showing the grain size of the sand as milled never approaches the line showing the average grain size of the silica sand. The silica sand is appreciably smaller than that of the batch of facing which exhibited the finest grain size.

Increase Is Pronounced

The influence of clay to increase grain size above that of the natural sand is so pronounced that we cannot help but believe that the constant addition of clay to sand will in the presence of water and under the action of mullers make the mixture coarser instead of finer up to that point where the strength of the envelop is not sufficient to resist the abrasive action in milling, which would tend to make fragments of the envelop spawl off. I hope later to ascertain at what stage of the continual introduction of clay such a tendency is observed. Supporting this statement are the figures obtained in determining the grain size of the various batches. The left hand column is a list by number of the sieves used in each test. The second column is the opening of the sieves expressed in inches. The third column gives the percentage retained by each sieve in the test of the washed and dried silica sand. The fourth column is the average of the percentages retained on each screen during the test of the facing sand. These averages were obtained by adding together the percentage retained on each test and dividing by the total number of tests. Column five indicates the percentage of increase in the amount retained on the individual screens; and column six the percentage of decrease. This table follows:

Sieve No.	Size of opening	Per cent retained silica	Per cent retained facing	Per cent increase	Per cent decrease
20	0.0331	0.15	0.84	460.0	...
30	0.0232	8.47	11.25	32.8	...
40	0.0165	26.82	34.90	30.1	...
50	0.0117	39.80	35.80	....	10.0
70	0.0083	14.39	10.10	....	29.9
100	0.0059	5.94	3.69	....	37.8
140	0.0041	2.79	1.91	....	31.5
200	0.0029	1.05	0.52	....	50.0
200+	0.0024	0.41	0.75	83.0	....
Total	.....	99.82	99.76	....	...

From these figures it will be apparent that a considerable

increase in grain size did occur and where it was most pronounced. In the cast of the original sand, 75.24 per cent was retained on the No. 20, 30, 40, and 50 sieves; while in the case of the sand to which clay had been added constantly, 82.79 per cent remained on the same sieves. Notice, too, that while the percentage retained on the coarser sieves increased, there was a decrease in the percentage on the finer.

Checking the Theory

To test the theory further, a sample was taken and its grain size determined. This sample was placed in a 240 mesh sieve and washed thoroughly. After washing it was dried and again tested for grain size. The change was marked as shown by the comparative figures in the following table:

Sieve No.	Sample as taken	Sample after washing
20	0.30	0.60
30	12.60	8.95
40	34.20	27.80
50	35.30	38.00
70	10.85	13.85
100	3.71	6.22
140	1.50	2.91
200	0.63	1.46
200+	0.81	0.22
	99.90	100.01
Average grain size.....	0.01403 inch	0.01309 inch

If the addition of clay tended to make sand finer, then the removal of that clay should reverse the process and make that sand coarser. In washing this sand we had taken clay from it, and our resulting sand had become finer instead of coarser.

Without dwelling longer on tests of similar nature, and some on the effect of heating, which would but make this paper longer, the writer wishes to call attention to the accompanying micrographs. Here it seems we have visible proof of the figures given.

Micrographs Prove Growth

Fig. 4 on page 10 shows a comparison between the original silica sand, and the same sand after having been through the mill twenty-two times, clay having been added each time, molds made from it and poured between each milling operation. The

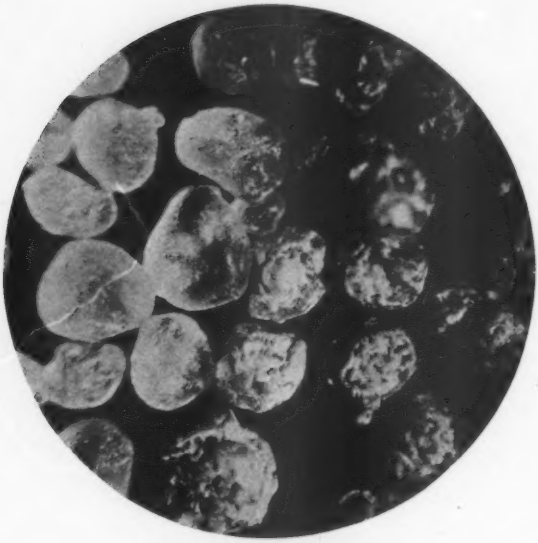


FIG. 4

FIG. 5

clear, smooth grains at the left are of the original sand; the irregular, warty grains at the right are after the repeated milling and use.

In the micrograph Fig. 5, the grains at the left are some of those warty grains shown to the right in the comparison with pure silica sand. At the right are other grains from the same sample after they had been rolled between two glass plates.

To the writer it seems that no great stretch of the imagination is necessary to see in the first a marked coating of the grain; and in the second, fragments of that coating broken from the grains.

Since, during the entire experiment, only clay and water were added to the pure silica sand, the change in the shape of the grains can be due only to a deposit of clay, which, in the presence of water, may possibly hold small grains of sand; and furthermore, the fragments shown can be nothing but parts of that deposit removed by the application of pressure or friction.

Requested by fellow members of the technical committee of the Electric Steel Founders' Research Group to explain the steadily increasing openess of his facing sand, described in the early part of this paper, the writer on several occasions advanced the snowball theory. However, he could not, prove that theory true until the conclusion of these experiments.

Discussion

H. M. LANE.—From your explanation of the sieve tests, did you ever take a sample of the original sand and the sand after the addition of clay 22 times and make the actual permeability test?

R. J. DOTY.—Yes. We have done that. I can perhaps better answer your question by referring to this facing sand. We started an investigation of facing sand which has now been going for about 20 months. We find that grain size is larger than at the start, in fact, there seems to be a tendency to still build up. The permeability, which increases constantly

for the first year, has ceased to increase. Occasionally, there is a recession from the high points with a building back, but in no case in our records have we seen a recession of the original permeability. I tried to explain that and make some plans to carry out some work to really study it and give the answer. My theory is that in the grain size those points have been built up to a point where there is a considerable amount of plastic material and those two walls are brought together with pressure enough to force toward the hard sand, forcing the envelope away from the round part.

H. M. LANE.—That is just exactly what I want to get out. The grain size is increased by the pressing of clay material around the original sand grains, then removing this clay film you may lessen the permeability of your sand.

R. J. DOTY.—It will take much longer than the time required for this experiment. We have been running 20 months now and there is nothing very marked about it. Sometimes that will last two or three days and again it will last for a week.

R. F. HARRINGTON.—Are you making a permeability test on the remainder?

R. J. DOTY.—No. That is made on the sand itself.

H. M. LANE.—You just place the sand in your tube without any ramming effect?

R. J. DOTY.—A very decided ramming effect. We want to guard against ramming it too hard. We took sands and with some elaborate experiments we figured averages showing just how the permeability increases with each ram. Our apparatus allows an eight pound weight to fall 30 inches. The plug in the top of our condenser is 4 inches in diameter. We found that with a curve—I can show you that curve if you will be interested. I have it here. I do not know how well you can see but I will show it here. These lines represent the number of rams. This represents the permeability factor, which we express as percentage. This curve represents the time required to pass a given volume of air through; and this curve represents the pressure exerted and

that, the pressure plotted against each ram. You see at this point the curve becomes pretty flat. There is a digression, or there is still a falling in the curve from that point there to this point here which will allow four different rams. That expressed percentages makes or amounts to less than two per cent. So all our tests are rammed five times. That is not the result of one particular sand; this represents the conditions in our plant.

R. F. HARRINGTON.—Your records will not indicate that all clay particles are flattened out in the ramming in such work?

R. J. DOTY.—No. I just have that theory. I find that for the last few months the permeability has shown a tendency to recede from the final point and that recession may last a few days or a week, but it comes back.

R. F. HARRINGTON.—And is your permeability test in any way equivalent to the condition you get in the event of the sand being rammed?

R. J. DOTY.—I feel so; of course, the test will not represent the condition where one particular spot is rammed.

S. H. CLELAND.—I would like to ask if the results obtained in Mr. Doty's shop were due to conditions peculiar to his shop and would, therefore, be a declaration of the conditions in respect to grain, character of clay and method of milling?

R. J. DOTY.—You mean, to duplicate them in any shop?

S. H. CLELAND.—Yes.

R. J. DOTY.—The conditions existing in the shop at the time of the experiment would have to be taken into consideration in the case of the heap sand, but if you are referring to conditions regarding the new sand, no. But in our every day practice, it would. The condition of heap sand would govern that.

S. H. CLELAND.—Would it be necessary for other departments to obtain similar results to overcome the same conditions you had and would you not have to have a rounder

grain and clay of the same general character and would not you have to mill it in the same general way?

R. J. DOTY.—I am of the opinion we should have a rounder grain. I do not know enough about the subject to state what would happen with an angular grain. We are getting too deep. It is done largely to regulate our own conditions or operations.

S. H. CLELAND.—Why would it not be possible in the milling machine to remove some of the clay?

R. J. DOTY.—I believe it is quite possible and very probable. In our particular practice we guard against it.

S. H. CLELAND.—So in other factories you would have to have almost a duplication of your methods to obtain similar results?

CHAIRMAN R. A. BULL.—That would be speculation, of course.

L. L. ANTHES.—I just wish to make a short observation and that is, the members of this association have been highly gratified by the work of your research committee, evidenced by the papers being given and I think we owe a debt of gratitude to Mr. Doty in putting himself to great inconvenience in telling us about this interesting subject and I should think the members of the research committee would be gratified. In the old days committees were discouraged because the members of the Association did not show sufficient interest. I think we can go back reinforced with the knowledge that next year in their papers further progress will be anticipated by the members of this association. I move a vote of thanks to Mr. Doty for his extreme kindness in staying over to read his paper for this special meeting. Seconded.

R. J. DOTY.—I feel very glad to do it. I am so much interested in this myself that I have to go into it.

Motion carried unanimously.

At this point Mr. F. L. Wolf replaced Mr. R. A. Bull as chairman.

A MEMBER.—I have done some work in Milwaukee with sand in our industry and the work has not been

thorough, because I have not had the time to devote to it. There are one or two things that have struck me about this. In ramming sand, I have found that there are some sands which, due to the nature of the bond, are such that you could not get a uniform ram with the same volume. Now, for that reason I have preferred to use in most cases a method of squeezing under a definite pressure. Now, that may be open to criticism but it is simply an attempt to get around another difficulty. Now, in regard to the ramming of sand such as we use; for testing for porosity or permeability, I am led to think that five times ramming is not sufficient to reach a maximum density. I should not say the maximum but in reaching the flat part of the curve. In some sands my experience has been that you should just ram this possibly once or twice more. There is one little thing I ran into which I have not noticed anybody else mention and which seems to me may have considerable significance on the question of sand and that is the formation of a crust on the grain of the sand in any surface. Now, when we put new sand into service there is probably a very slight coating of oxide on the grain. Some of it, of course, is clay substance, some of it is very fine silica which collects around each particular grain. The longer you use it the more that builds up. Now, in certain cases that is very valuable; as a matter of fact, it is valuable in my estimation with no exception in any case. In some cases it is absolutely essential. We have considerable trouble in buckling whether due to there not being sufficient film of sand or of crust on the grain; that also affects the action of slicking which we get in our ramming. A grain which is free of this crust, will not slick as much as sand with crust on; and that is worth considering.

Establishing a Method of Testing for Green Bond Strength

By R. J. Doty, Milwaukee

A little more than a year ago at the request of the Electric Steel Founders Research group, the Sivyer Steel Casting Co. undertook an investigation of the facing sand problem. It was believed that in such an investigation comparisons of one sand with another would be essential, and it was felt that sands could not be compared unless some value could be given to them or to the properties which they possess.

The first effort was to decide upon those properties which were believed essential to a good facing; and the next, to define in some manner the extent to which any of the sands under investigation possessed those properties.

Any member may decide to try in his foundry any one of the experimental mixtures on which we have reported good results. To make a fair trial he should know that the sand mixed in his mill is a duplicate of the sand mixed in ours. To be sure that they are alike, he will have to know that his sand possesses to the same degree as our own those properties which brought about the results noted in this paper. In order that he may know, tests had to be provided for determining those properties, and those tests had to be not only reliable in our laboratory, but so standardized that they will give true comparisons in any laboratory.

It was easy to decide the properties which should be compared, but to find tests which should determine accurately the degree to which any sand possessed these properties was a more difficult problem.

This paper will attempt to give an account of the attempts to establish a reliable method of testing for green bonded strength, and will describe as briefly as possible some of the experiments with the results obtained by each. It will also give some of the reasoning which led us from one experiment to

another until we developed the method which we are now using daily as a part in the control of our facing.

In testing the strength of any material, there are but two directions in which the force is commonly applied, namely in the direction of the principal axis or at right angles to it. For some materials the tensile test is the best strength criterion; for others, the transverse test finds the best application. Investigators of sand have chosen the latter, and have almost invariably determined the strength by pushing the test bar lengthwise over a plate until the overhang broke off under its own weight.

In preliminary experiments with facing sand used in the Sivyer foundry, the transverse test was first used, and it was evident that the density to which the sand was rammed would have a great effect upon the strength of the material. Since hand ramming was unreliable, a core box was so constructed that a volume of sand 10 x 1 x 1¾-inch was in each case compressed to a core 10 x 1 x 1-inch, the compression being entirely from the top by means of a ¾-inch projection on the cover which formed the top of the box. The box referred to, and a core made from it are illustrated in Fig. 1.

The box in this and following experiments was filled by pushing the sand with the fingers through a ¼-inch riddle, resting on the top of the box, any excess sand being removed before ramming by means of a glass plate, used in the same

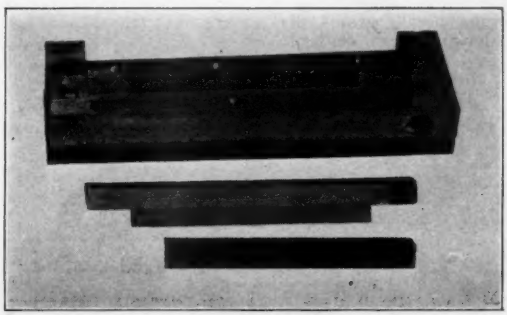


FIG. 1—CORE BOX AND CORE FIRST USED IN TESTS

Table I

	Bar 1	2	3	4
Break 1 (cm.)	5.09	5.7	6.45	5.4
Break 2 (cm.)	5.09	5.16	6.20	5.08
Break 3 (cm.)	4.78	4.94	6.12	6.70
Average	4.99	5.27	6.26	5.72
Deviation (Max.) per cent	4.2	8.2	3.2	17.5
Average maximum deviation, per cent				8.27
Grand average, centimeters				5.56
Maximum deviation, per cent				20.1

Table II

Break	1 grams	2 grams	3 grams	4 grams	5 grams	6 grams
1	67.9	58.0	66.5	60.0	67.1	61.8
2	60.0	61.2	58.6	72.1	61.2	65.2
3	67.2	61.2	56.0	63.0	61.7	65.2
4	62.0	59.0	57.5	60.6	58.0	65.2
5	60.0	62.1	61.7	61.0	58.0	61.7
Average	63.4	60.3	60.0	63.3	61.2	63.8
Max. dev. per cent	7.1	3.8	10.8	13.9	5.2	3.3
Average maximum deviation, per cent						7.35
Grand average break, grams						62.03
Maximum deviation, per cent						16.1

Table III

Group	1 grams	2 grams	3 grams	4 grams	5 grams	6 grams
Bar 1	198.0	193.0	223.0	256.0	221.0	202.0
Bar 2	208.0	220.0	210.0	220.0	208.0	294.0
Bar 3	200.0	173.0	210.0	262.0	200.0	288.0
Bar 4	181.0	187.0	243.0	249.0	176.0	290.0
Bar 5	226.0	187.0	258.0	296.0	300.0	205.0
Average	202.6	192.0	228.8	256.6	221.0	255.8
Max. dev. per cent	10.7	14.6	11.9	15.6	35.7	21.1
Average maximum deviation						16.76
Grand average break, grams per square inch						226.1
Maximum deviation, per cent						32.7

Table IV

Lubricant	No. 1 sand grams	No. 2 sand grams	No. 3 sand grams
None	110	125	122
Oil	105	93	101
Silica sand	94	76	99
Paper	67	73	60

manner as a molder uses a strike. The cover of the box was then forced into position, forming the core described above. After removal of the cover and the bottom, both of which were doweled to the sides of the box, the core supported by the sides of the box was transferred to a glass plate, and the sides removed after the core was placed. The core was then slowly and steadily moved endwise across the plate until the weight of the overhanging section caused the bar to break, and the length of this broken section taken to secure a figure indicating the strength of the sample. The data obtained by repeating this operation three times on each of four bars from the same sample is shown in Table 1.

In each case the fractures were so irregular that it was possible to get different values of length, depending upon the part of the fractured section measured. The next step then was to weight the overhanging section rather than to measure it. In this case, regardless of the result obtained, it was certain that the result was a true value and not merely a well directed guess. Table II shows some of the results obtained by weighing the overhanging section.

We realize that the results obtained by the preceding methods, though they show a variation, might be sufficiently accurate to indicate the strength. However, they would be of value only for comparative purposes since they are but abstract numbers.

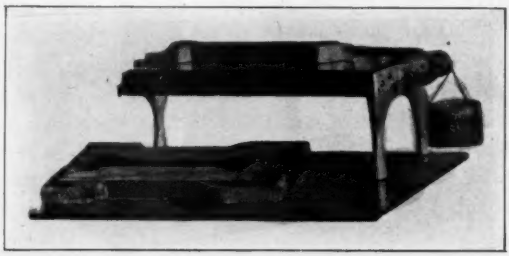


FIG. 2—HORIZONTAL TENSILE TEST TABLE, SHOWING CORE AND CLAMPS IN PLACE

To obtain a concrete stress value by these methods would necessitate the use of lengthy computations involving use of the length of overhanging section. Although comparative figures might prove sufficient for present purposes, concrete values would be of far greater service.

To obtain concrete values it was decided to try the tensile test in which the strength of the sand could be determined directly in grams per square inch. We felt that a green sand core, with cross-sectional area of 1 square inch, would be too delicate to handle in any of the common methods for obtaining tensile strength, and for this reason our first efforts to investigate tensile strength of sands resulted in the designing and building of the horizontal tensile test table, and a core with enlarged shoulders to receive aluminum clamps, shown in Fig. 2.

After ramming, the core suspended between the sides of the box was placed on the glass top of the table. The sides were removed and the aluminum clamps carefully adjusted. The load was applied by dropping sand into the container which hangs below the sheave shown at one end of the table. In this method many new difficulties were encountered, one of the most important being the friction between the core and the plate. Because of this friction, the pull was not distributed to all sections of the core, but was concentrated upon the point of application; hence all the cores broke at the shoulder. Results found by this method were variable, as can be seen by referring to Table III.

FIG. 3—COREBOX IN WHICH SHORTER CORES WERE MADE

In this table the value shown in grams is the load per square inch under which each bar broke. Since this experiment was conducted to demonstrate the reliability of a method, the work was carried out as follows:

A quantity of facing sand sufficient for the test was placed in a humidor to maintain the same moisture content throughout the work. Five bars were made and then broken. These bars gave the results shown in the column marked Group 1. In the same way five bars were made and broken in Groups 2, 3, 4, 5, and 6, so that a total of 30 bars were made from the same sand, under the same conditions, and broken.

To determine the maximum percentage of deviation of each bar, the difference between the average for that bar and its most divergent result is divided by the average value. The average maximum deviation is a numerical average of the maximum deviations of the individual bars.

The absolute maximum deviation for the entire table is calculated as for each bar, except that the average of all the values is employed.

Is Necessary to Change Core

Since all of the cores broke at the shoulder, it was decided to shorten the core and also to try to decrease the effect of friction by the use of parting materials. In shortening the core, we constructed a box having the dimensions of a standard cement briquette. This core was rammed by top compression of ¾ inch and is shown together with its corebox in Fig. 3.

Silica sand, oil and strips of waxed paper were used as parting materials, giving the frictional value shown in Table IV.

Since strips of paper gave the best results, they were used in tests whose values are given in Table V. We realized that the load necessary to break the bar might be affected were it necessary to tear the paper. For this reason we placed two strips of paper, separated by about ¼ inch, under the bar. The space between the strips was at the center of the bar where the rupture would take place.

A study of this table and a comparison with Table III will show you that though we had reduced friction to a mini-

Table V

Group	1 grams	2 grams	3 grams	4 grams	5 grams	6 grams
Briquette 1.....	248	173	221	208	200	181
Briquette 2.....	226	187	193	220	173	187
Briquette 3.....	223	210	210	243	258	256
Briquette 4.....	220	262	249	296	221	208
Briquette 5.....	200	176	300	202	294	288
Average	223.4	201.6	234.6	233.8	230.2	224.0
Max. dev. per ct.	11.0	25.0	27.9	26.7	27.8	28.6

Average maximum deviation, per cent..... 24.5
Grand average break, grams per square inch.....224.6
Maximum deviation, per cent..... 33.6

Table VI

Group	1 grams	2 grams	3 grams	4 grams	5 grams	6 grams
Briquette 1.....	335	320	435	310	346	271
Briquette 2.....	285	305	304	420	371	297
Briquette 3.....	305	363	425	300	301	360
Briquette 4.....	320	272	303	280	440	300
Briquette 5.....	362	406	360	320	284	330
Average	321.4	331.2	365.4	326.0	348.4	311.6
Max. dev. per ct.	12.6	20.8	16.7	28.8	26.4	15.6

Average maximum deviation, per cent..... 20.16
Grand average break, grams per square inch.....334.0
Maximum deviation, per cent..... 30.2

Table VII

Group	1 grams	2 grams	3 grams	4 grams	5 grams	6 grams
Briquette 1.....	382	403	433	370	412	390
Briquette 2.....	312	342	282	300	302	280
Briquette 3.....	358	390	398	430	378	450
Briquette 4.....	352	360	312	365	332	385
Briquette 5.....	317	363	350	371	330	351
Average	344.2	371.6	355.0	367.2	350.8	371.2
Max. dev. per ct.	10.75	8.5	24.8	18.5	17.7	24.5

Average maximum deviation, per cent..... 17.46
Grand average break, grams per square inch.....360
Maximum deviation, per cent..... 25.0

Table VIII

Group	1 grams	2 grams	3 grams	4 grams	5 grams	6 grams
Briquette 1.....	454	460	490	415	473	439
Briquette 2.....	414	424	400	421	422	438
Briquette 3.....	465	484	441	491	440	465
Briquette 4.....	474	463	453	440	455	480
Briquette 5.....	490	470	550	450	500	447
Average	459.4	460.2	466.8	443.4	458.0	453.8
Max. dev. per ct.	7.8	7.85	17.80	10.60	9.20	5.95

Average maximum deviation, per cent..... 10.20
Grand average break, grams per square inch.....456.9
Maximum deviation, per cent..... 20.40

mum, we had accomplished nothing else. In each table it will be noted that the average load causing rupture of 30 bars was practically the same, being 226.1 grams per square inch in Table III, and 224.6 grams per square inch in Table V.

You will also note that with the decrease in friction, there was an increase in the average maximum deviation from 16.76 to 24.5 per cent.

Sand in Working Parts Affects Results

During the experiments which were conducted in connection with this table, we found that we had an element to contend with other than the friction of the core on the table top. No matter how careful one may be in handling sand, it is impossible to keep all of it out of important working parts, such as the bearing of the sheave over which the load was applied, and we found in some cases where the test bar showed a higher tensile strength that the load necessary to break the bar was increased by the friction of the cord over the sheave when the sheave was prevented from turning by sand. Various means of eliminating this uncertainty were devised, but in the end we realized we would have to abandon a horizontal tensile test, because the possibility of error creeping into our determination through some cause, such as the one just referred to, was too great.

The next step was to design a gallows, allowing the force to be applied vertically, as shown in Fig. 4.

We found it was necessary to make the core strong enough to uphold not only its own weight, but the weight of the clamp and container as well, hence the amount of compression of the box shown in Fig. 3 was increased from ¾ to ⅞-inch. The load was applied by pouring silica sand into the container. With this method the results were still very variable as may be seen from table VI.

We believed that the factors having the greatest effect upon the results were, first, time of suspension; second, rate of increase in load; third, uniformity of ramming core; fourth, strains set up in core during manipulations. Therefore, to eliminate the first two factors, the apparatus was modified so that

a slow stream of water under constant pressure was used in place of silica sand. The pinch-cock, just under the shelf, when opened allowed water to siphon from the bottle through a small glass orifice, shaped like a medicine dropper, in the lower end of the black rubber tube which shows just above the bucket in Fig. 4.

The third, and most important factor, was one that required a great deal of study and attention. Every foundryman knows that when sand is rammed, that portion of the sand which is farthest away from the rammed surface, is least dense, consequently the cores varied from a great density at the top surface to a lesser density at the bottom. For this reason we determined to construct a box which would permit of top and

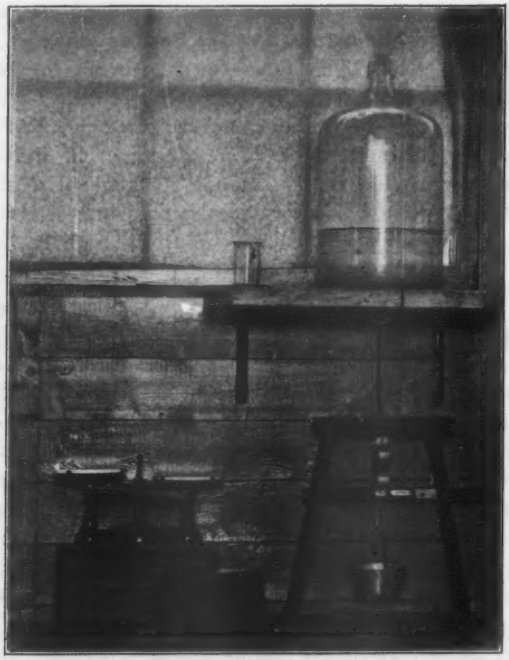


FIG. 4—A GALLOWS FOR VERTICAL TENSILE TESTS

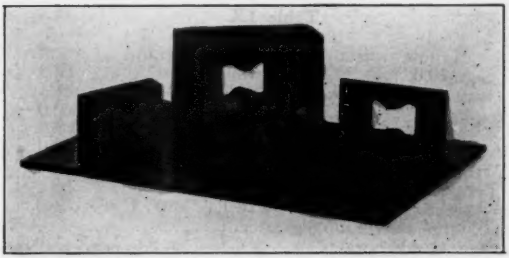


FIG. 5—A COREBOX PERMITTING TOP AND BOTTOM RAMMING

bottom ramming so that our core might be rammed by equal pressure or by an equal amount from two sides. Then, since the rammed surfaces would be more dense than the center of the core, we determined to shave off both rammed surfaces. A new box designed to permit these manipulations was constructed, and is shown in Fig. 5.

By using this box we were enabled to produce a briquette 1.6 inches high by compressing from top and bottom a similarly shaped volume of sand 3 inches high. This briquette is shown at the left of the illustration and is held in place by the loose pieces 1-inch thick. You will notice that the briquette projects beyond the wodden side. It does, in fact, project .3 of an inch to each side. Thus by holding the loose pieces tightly, we were able to strike off .3 of an inch from the top and bottom of the original volume, leaving a briquette 1 x 1-inch from the very heart of the original volume, and rammed uniformly from top to bottom.

Cores made by this method were tested, and the results found on six groups of five each are shown in Table VII.

You will see that the results shown by this table are more uniform, but we were convinced after several repetitions of this experiment that results would not check one another close enough to be of practical value.

All of the core boxes thus far used had a neck which was but one inch across, and it was thought very probable that in filling this narrow neck some bridging of the sand occurred. Such bridging would affect the volume of loose sand entering

Table IX

Bar Group	1 grams	2 grams	3 grams	4 grams	5 grams	6 grams
Break 1	70.0	80.7	61.3	62.4	67.3	66.1
Break 2	63.5	70.2	58.1	52.9	68.1	68.3
Break 3	61.7	63.5	53.1	61.3	60.0	67.3
Break 4	64.0	64.0	60.7	58.1	65.9	60.0
Break 5	63.9	63.9	62.9	62.9	60.0	60.0
Average	64.62	68.46	59.22	59.52	64.26	64.34
Max. dev. per cent	8.35	18.0	10.3	11.1	6.3	6.7

Average maximum deviation, per cent 10.11
Grand average break, grams 63.40
Maximum deviation, per cent 27.5

Table X

Bar	1	2	3	4	5	6
Break 1	72.3	78.6	68.0	81.6	79.1	80.3
Break 2	67.5	64.1	72.3	76.1	78.4	81.2
Break 3	68.5	72.3	74.8	68.0	71.1	78.6
Break 4	72.3	67.5	70.8	72.3	79.4	79.0
Break 5	76.2	68.5	86.0	75.0	72.5	71.2
Average	71.36	70.20	74.38	74.60	76.10	78.06
Max. dev. per cent	8.30	11.95	16.90	9.37	6.58	4.03

Average maximum deviation, per cent 9.52
Grand average break, grams 74.11
Maximum deviation, per cent 16.10

Table XI

Bar	1 grams	2 grams	3 grams	4 grams	5 grams	5 grams
Break 1	105.0	103.0	95.3	110.0	87.7	105.0
Break 2	106.3	99.0	102.2	102.2	89.0	107.8
Break 3	100.0	89.3	97.7	89.7	87.6	97.6
Break 4	97.3	100.0	90.0	84.5	95.6	97.6
Break 5	102.5	109.0	95.6	96.4	97.5	99.6
Average	102.22	100.06	96.16	96.56	91.48	101.52
Max. dev. per cent	4.80	10.70	6.35	12.40	6.68	6.20

Average maximum deviation, per cent 7.85
Grand average break, gram 98.0
Maximum deviation, per cent 13.75

Table XII

Bar	1 grams	2 grams	3 grams	4 grams	5 grams	5 grams
Break 1	109.3	108.6	112.1	116.9	110.0	112.5
Break 2	114.6	111.2	111.4	116.9	112.0	113.0
Break 3	115.6	123.2	120.9	121.0	127.0	116.1
Break 4	116.7	124.1	123.0	117.0	127.0	119.5
Break 5	128.5	124.0	122.6	124.0	126.3	117.0
Average	116.9	118.2	115.6	119.2	120.4	115.6
Max. dev. per cent	9.9	8.1	6.4	4.2	8.7	2.7

Average maximum deviation, per cent 6.66
Grand average break, grams 117.6
Maximum deviation, per cent 9.35

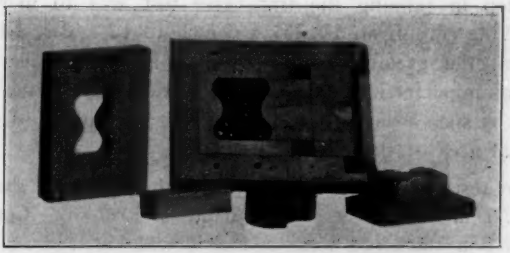


FIG. 6—COREBOX IN WHICH NECK OF CORE IS MADE LARGER THAN IN BOXES PREVIOUSLY SHOWN

the box, increasing it in some cases and decreasing it in others, thus affecting the density of the ramming. To eliminate this possibility as far as possible, a box was constructed which had a minimum opening of two inches during filling, which opening was later reduced to one inch by side compression of the sand and a final top compression completed the core. Fig. 6 shows the construction of this box.

From this box thirty briquettes were made in six groups of five each and tested. The results are shown in Table VIII.

These results are more uniform than any of those obtained so far by us in endeavoring to develop a tensile test which would give the green bonded strength of a sand in grams per square inch.

A study of the results obtained thus far taken in conjunction with the theoretical considerations involved show that the horizontal tensile and the first of the vertical tensile methods have been eliminated as unreliable. Furthermore, the results obtained in the vertical tests by the best ramming methods we could devise only approximately equalled the results obtained with a crude corebox in the transverse test. Also, since the transverse test would decrease the possibility of straining the core in manipulation and thus be better suited for the weaker sands, it was deemed advisable to abandon the tensile and devote our energy to refining transverse method.

Having learned by our investigation of the tensile test that a wide box gave more uniform results than a narrow box, our

first step in refining the transverse test was to increase the size of the core from 10 x 1 x 1-inch to 12 x 2 x 1-inch. In addition, the greater width of the core should decrease the effect of imperfections such as small pebbles, since the area occupied by such a flaw would be a smaller percentage of the cross sectional area of the core.

To test this theory a box was built similar to that shown in Fig. 1 in all respects except width and length. Cores made in this box therefore were 2 inches wide instead of one, but were rammed by top compression only.

These cores being twice as wide, were approximately twice as heavy, so it soon became apparent that some were strained and some actually broke while transferring them from the box to the glass plate. To overcome this difficulty the glass plate was made a part of the bottom of the corebox. This permitted us to remove the core from the box without injury. The results obtained by 30 breaks on six bars are shown in Table IX.

The results shown were not encouraging, but we believed the theory was right; so remembering our experience with the tensile tests, we constructed another box of the same size, but designed for ramming from both sides and from the top.

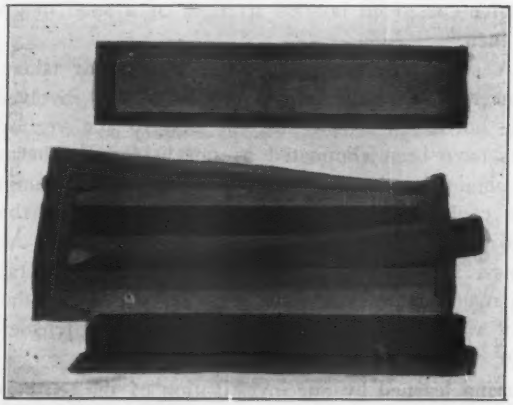


FIG. 7—COREBOX PERMITTING RAMMING FROM THREE SIDES

FIG. 8—A BOX SIMILAR TO THAT SHOWN IN FIG. 7, BUT 4 INCHES LONGER

This gave us a core 12 x 2 x 1-inch rammed from three sides. This box is shown in Fig. 7.

Table X shows that the results of tests on cores made in this box were more uniform than those obtained in previous tests, but they were not satisfactory.

In our manipulations of this box we encountered several mechanical difficulties which in our opinion had some effect on the results secured. To overcome these, a larger and more sturdy box was constructed, which permitted of several refinements, and which gave us a core of the same cross section, rammed in the same manner as the box just referred to.

When, after each test, we tabulated and studied the results, we seemed to note that the result obtained for the first break on each bar was in many cases the most divergent. We felt this was due to the way in which the sand fell against the end of the box during the filling operation. As we saw no way of overcoming this, we felt that at some later test we might have to discard the first break and consider only those from the center of the box. In the case of a strong sand which would permit of a longer overhang, this would greatly reduce the number of breaks per bar. As we were about to build a new box, it seemed advisable to provide for this, so decided to increase the length from 12 to 16 inches. The new box is shown

in Fig. 8. The results obtained by testing cores made in this box are shown in Table XI.

This table shows the values were much more uniform than those obtained by any method so far tried. Further, a study of this table will indicate that various breaks on the same bar check one another closely, though the average of the various bars do not check as well. All the bars were made from the same sand, so we were led to believe that each bar was rammed uniformly throughout its length, but all the bars were not rammed alike.

In every case the box had been filled by forcing sand by hand through a ¼-inch riddle resting on top of the box. This practice had been adopted as the most logical way of introducing sand into the box. Our deductions based upon the fact pointed out by Table XI, made us realize in a concrete way that the sand could not have been introduced uniformly each time the box was filled. Instead of uniformity in filling, we must have had variations.

In an attempt to eliminate such variation in filling, a riddle was constructed with dimensions corresponding to the opening in the box. To make sure that the riddled sand in filling the box would in every case fall through a given distance, suitable guides were provided and fastened securely to supports at each end. These guides also confined the motion of the riddle to travel in a straight line. Blocks at each end of the guides

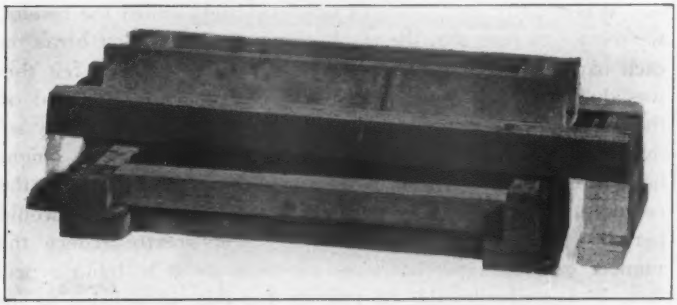


FIG. 9—RIDDLE USED IN FILLING COREBOX

limited the motion to travel through a given distance. Rubber strips on these blocks eliminated severe shocks which might have caused the sand to settle in the box during the filling operation. This riddle is shown in Fig. 9.

To test this method, the core box was placed under the riddle, which contained a number of stars, and filled to slightly overflowing. The excess sand was removed by striking off and ramming completed as in previous tests. Table XII gives the values obtained, and a closer uniformity than by any method so far tried.

In Table XIII we have compiled the average and maximum deviations of tests one to 12 inclusive taken from the tables already given, with statements indicating the manner of conducting each test.

The results given by our last test showed up so well when compared with all previous tests that we believed the method to be reliable, but before adopting it, decided to try it out.

To insure a real test, we proceeded as follows:

Ample samples of two different sands were placed in the humidor. Three trials were made of each sand. Each trial covered the making of three cores at one time, and then breaking them. For the reason already mentioned, it was decided to discard the first break so that each trial gave 12 breaks Table XIV gives the results of these two tests.

Here we were testing two sands of different strengths, and in each case the result of 12 breaks from three bars checks with the results of 12 breaks from each of two other groups of three bars. The tests proved the method to be more reliable than we had hoped it could be.

We felt then that we had established a standard method for testing for green bonded strength which would be reliable and of value, for comparative purposes at least, over a long period.

With this feeling of assurance, we started the mixing of experimental facings, and to our estimate of the values of the successive batches as regards green bonded strength, was added the findings of the laboratory. These findings confirmed in

Table XIII

Table No.	Nature of test	Method of filling	Method of ramming	Unit of measurement	Remarks	Ave. deviation Per cent	Max. deviation Per cent
1	Transverse	Hand Riddle	Top	centimeters	.....	8.27	20.10
2	Transverse	Hand Riddle	Top	grams	.....	7.35	16.10
3	Tensile-Horiz.	Hand Riddle	Top	grams	Long core	16.76	32.70
5	Tensile-Horiz.	Hand Riddle	Top	grams	Short core	24.50	33.60
6	Tensile-Vert.	Hand Riddle	Top	grams per sq. inch	Short core	20.15	20.20
7	Tensile-Vert.	Hand Riddle	Top	grams per sq. inch	Short core removed from each side	17.46	25.00
8	Tensile Vert.	Hand Riddle	Top and side	grams per sq. inch	Short core	10.20	30.40
9	Transverse	Hand Riddle	Top	grams	12-inch core	10.11	27.50
10	Transverse	Hand Riddle	Top and side	grams	12-inch core	9.52	16.10
11	Transverse	Hand Riddle	Top and side	grams	16-inch core	7.85	13.75
12	Transverse	Sliding Riddle	Top and side	grams	16-inch core	6.66	9.35

figures what we could express only as an impression based upon our sense of feeling and our judgment.

It was then with satisfaction and pleasure we produced batch after batch of facing, often repeating experiments and checking results to secure certainty. Whenever we increased the clay content of a batch, our senses told us the bond was greater; and the laboratory not only confirmed this, but in addition, gave us a figure representing that increase. For some time this situation continued to our extreme satisfaction, and then the unexpected happened.

We mixed a batch of facing which in our opinion was too dry, but the strongest we had made to date. The laboratory gave it the green bonded value of 247.7. We determined to duplicate this batch, raising the moisture content. The second batch felt stronger than the first, but the laboratory gave it a green bonded value of 119.06, less than half the strength of its mate.

Believing some error had been made in the laboratory, and all the sand having been used, we duplicated the batch on the next day, but found the laboratory checked itself satisfactorily. To satisfy everyone, a recheck was made on the same sand, and with the same result.

Because the writer had every faith in the test itself and the manipulations connected with it, he looked first of all to the milling of the sand. Having personally mixed every batch, he knew that as the sands became stronger, the plows had acted as dams, decreasing the amount of sand under the muller.

Various adjustments of plows were tried, and increases were made in the milling period, but without changing the result as shown by the laboratory. Tests showed this mixture to be far weaker than those immediately preceding it, though its clay content had been increased 25 to 50 per cent over those batches and our judgment estimated it to be stronger.

Could the testing method be wrong? To check this out the plows were readjusted and a number of batches, duplicates of No. 1, were mixed until that adjustment was secured which with the original milling period gave sand of the same strength

as the original No. 1. Thus we were evidently rigged up as at the start.

Our next move was to repeat each second batch and ascertain the green bonded strength. The values found checked unbelievably close to our original findings. This, in view of the sudden drop in our last batch, was hard to credit, so we duplicated every batch and again secured the green bonded strength. The values obtained again checked very closely with our first findings.

If you will look at Fig. 10 you will see that the green

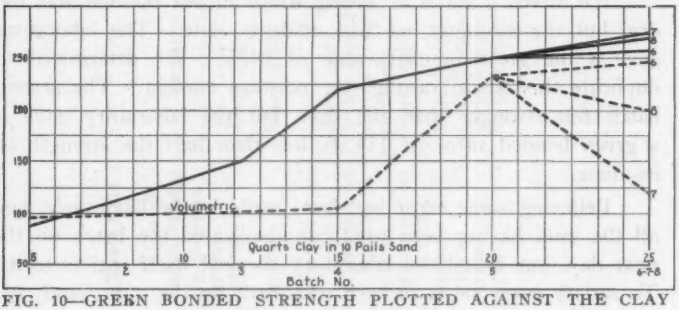


FIG. 10—GREEN BONDED STRENGTH PLOTTED AGAINST THE CLAY CONTENT OF EACH BATCH

bonded strength of the various mixtures is plotted against the clay content of each batch. The values we have been discussing are represented by the broken lines. In the batch at the extreme right there are three different values for green bonded strength. These values correspond to the different amounts of moisture content in those batches, the clay content being the same in each.

We stopped making experimental sand and tried to reason it out. We re-read our notes, we recalled and discussed all the phenomena we had noted during our work.

In all of the experiments performed through Batch No. 6, the laboratory results in every case had agreed with our observations. With an increase in the proportion of clay to sand an increase in the green bonded strength as determined in the

laboratory always occurred, though this increase in some cases was small and seemed to have no relation to the amount of clay present. Table XV shows that in the first six batches an increase in the clay addition resulted in a stronger facing, and it also shows that this rule did not hold good in Batch No. 7.

In making the various bond tests, various properties had been noticed about all of the test bars. Among them was the fact that the greater the proportion of clay or moisture, the more easily could the bar be rammed and with repeated increases in the clay, or moisture content, the test cores began to have a coarser texture and a seemingly greater proportion of voids. These properties became more noticeable with each succeeding batch until the bars from the seventh mixture, which contained a high percentage of clay and increased moisture, became so weak as to actually crush beneath the force necessary to move the bar across the plate. On the other hand, our sense of feeling and our judgment firmly established this sand as the strongest made thus far, an impression directly opposed to the laboratory finding of the low value of 119.6.

The redeeming fact in this situation was that good checks were secured on any one batch, proving the basic principle, of the method employed, not at fault.

Equal amounts of the same sand rammed to like condition should have the same bonded strength, equal amounts of different sands rammed to like condition should give results in accordance with the true properties of those sands. Evidently then Batch No. 7 should have a higher bonded value than that determined by the laboratory.

The construction of our corebox was such that in each test we were compressing to the same final volume the same quantity of sand, measured volumetrically. From this statement it is apparent that we should have then in each cubic inch of each final bar the same amount of sand.

We have stated that an increase in clay content made the cores ram more easily and that an increasing openness of tex-

Table XIV

	—Test No. 1—Sand "A"—			—Test. No. 2—Sand "B"—		
	Trial 1	2	3	1	2	3
	grams	grams	grams	grams	grams	grams
	126.3	122.6	128.5	146.0	156.3	150.0
	127.0	123.0	116.9	147.8	168.1	150.0
	127.0	120.9	116.7	146.1	166.9	145.6
	110.0	110.0	118.2	155.0	175.0	147.6
	107.0	111.4	115.6	162.6	157.2	153.6
	124.0	116.1	115.6	154.7	164.5	149.6
	117.0	124.0	114.6	170.0	150.6	156.2
	121.0	124.1	119.2	175.0	154.5	155.1
	116.9	123.2	109.3	172.4	161.4	165.1
	116.9	111.2	120.4	165.0	160.0	173.3
	119.5	108.6	112.5	151.5	160.0	171.4
	112.0	113.0	115.6	167.4	157.3	164.2
Average	118.7	117.3	116.7	159.4	160.6	156.8

Table XV

Batch	Clay per cent	Moisture per cent	Green bonded strength
1	5	4.95	96.5
2	8	5.05	98.0
3	12	3.55	101.5
4	15	3.40	107.3
5	20	2.84	239.7
6	25	3.15	247.7
7	25	3.85	119.6

Table XVI

Batch	Clay	Moisture	Weight of bar
1	5	4.80	958.0
3	12	3.53	778.4
5	20	3.30	812.4
6	25	3.40	895.6
7	25	3.95	760.1

Table XVII

	Weight of one quart	Grain size (inches)
Silica sand	1240 grams	.01188
Fire clay	1270 grams	.01144
Fifty per cent silica sand and 50 per cent fire clay	1405 grams	.01162

Table XVIII

Batch	Clay	Weight per quart	Grain size
1	5	1206	.01172
2	8	1180	.01200
3	12	1117	.01319
4	15	1100	.01325
5	20	1092	.01373
7	25	1075	.01394

ture had been noted. This would seem to indicate that we could not be ramming the same amount of sand into the same final volume.

Our next move was to find if we were putting the same amount of sand into the corebox. Batches Nos. 1, 3, 5, 6 and 7 were duplicated and test cores were made from them by measuring the sand volumetrically as before. After ramming, the weight of each core was determined, and the results compared in Table XVI. An examination of this table will show the variation in the weights of the bars from the different batches.

An investigation then was undertaken to determine, if possible, the cause of this phenomenon. We believed that we were displacing some silica sand in each core when we increased the clay content of a batch. Could the clay be lighter than the sand, thus decreasing the weight of the bar? We accordingly dried some sand and clay and weighed each. We found the clay to be the heavier, which would indicate that the core should be heavier if one grain of clay displaced one grain of sand. Having arrived at this point, our next step was to determine the grain size of each. We found the clay to be finer, hence were led to believe that each grain of clay would not displace a grain of sand, for being finer, some of the clay would enter some of the voids between the grains of sand.

To determine to what extent the clay would fill the voids, or expressed differently, what would be the resulting volume of a mixture of equal volumes of sand and clay, we mixed thoroughly together, one quart of sand with one quart of clay. The resulting volume was 1.8 quarts. This would indicate that 10 per cent of the clay went into the voids.

From this we were led to believe that even should the clay be lighter than the sand, we should by increasing the clay content up to 10 per cent of the sand have a heavier core than we started with, for by filling the voids, we should have the additional weight of the clay. By weighing a quart of the mixture of equal volumes of sand and clay, we found this to be true.

A study of Table XVII will show that one quart of dried

silica sand having a grain size of .01188 inch weighs 1240 grams; and one quart of fire clay having a grain size of .01144 inch weighs 1270 grams. When these materials were mixed in equal quantities in the dry state, the resulting mixture had a grain size of .01162 inch, and weighed 1405 grams per quart. This clearly shows that in a dry condition, clay fills in the voids of the sand, causing a finer and heavier mixture.

Having proved that the introduction of clay increased rather than decreased the weight of a given volume of sand, we were still confronted with the fact that an increase in clay content in the facing sand resulted in a loss of weight. We recognized at this point two factors which would have a decided influence on the problem.

In this test the addition of dry clay to dry sand resulted in a mixture whose grain size was less than that of the sand itself. In testing facing we have found that the addition of fire clay to sand increased the grain size. Since in both we used the same sand and clay, the only difference then could be through the moisture in the facing.

This would indicate clearly that when sand and clay are milled together in the presence of water, either the grains of sand become coated with a film of clay, or they pick up particles of clay. Either would increase the grain size in the same manner as a snowball is built up when rolled on snow.

You will agree that a decrease in the weight of a given volume of sand and clay could not be brought about by the introduction of water, since water would enter the voids and increase the weight.

Having proved that manual additions of clay and water increase the weight of a specimen of given volume, we then had to consider the fact that these when added in a mill might have the opposite effect by building up the grain size, and perhaps increasing the voids.

To test this theory, Batches Nos. 1 to 7 inclusive were duplicated, using the same sand and clay. Samples of these batches were dried and the weight per quart and grain size were

determined. Table XVIII shows that in each case the mixture was coarser and lighter after drying than the original silica sand. Here we see that an increase in grain size brings a decrease in the weight of a given volume of sand. Consider that the measure in this test was filled with dry sand, reducing bridging to a minimum, and you will see that we felt we had the answer to our problem.

All of our test cores were made of sand containing moisture. Add bridging of damp sand to increased grain size, and the result is that though we were placing in our corebox the same volume each time, we were not introducing the same amount of sand. This volume consisted of facing and of voids. With each addition of clay we were introducing a smaller volume of sand and a larger volume of voids.

In Fig. 11 we have plotted increase in grain size against decrease in weight. The result would indicate that the change is very consistent for the curve is practically a straight line.

If we are to approach the ideal condition of having for all tests the same total surface of non-bonding material upon which the bonded substances may act, it is evident that a volumetric measurement of quantity will not suffice. We have shown that

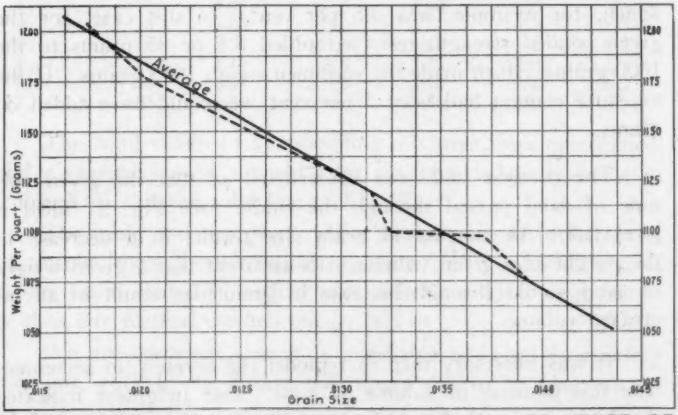


FIG. 11—EFFECT OF GRAIN SIZE UPON WEIGHT PER QUART OF FACING SAND

the strong sands actually have less material per quart than the weak ones, and hence the bonding effect of a greater amount of clay was counterbalanced by the lesser degree of ramming.

The ideal method would be to count out the proper number of grains for each test, but this is impractical. The other alternative is to weigh the sample. In the gravemetric method, however, one precaution is necessary. A definite weight of a wet sand contains less actual sand substance than a mixture containing a lower percentage of moisture.

To guard against such an error, we determined to first evaporate the moisture from a part of our sample, and having ascertained the amount contained, to increase the weight of our test specimen by that amount. It was found, by trial, that one thousand grams of sand would produce a test bar of such density as to be satisfactory for all sands in which we were interested.

Our procedure then was as follows:

The investigator secured from the mill a sample large enough to carry out all tests. This was put into the humidor. One hundred grams were taken for the moisture determination, which, for example, was 3.5 per cent. In this case, for the green bonded strength test, we added 3.5 or 35 grams to the 1000 grams, which made the specimen weigh 1035 grams. If the moisture content had been 3 per cent we would have added 30 grams.

The corebox had been constructed so that the given volume of sand passed through the riddle (see Fig. 9) filled it level full. As increase in grain size results in a decrease in the weight of a given volume, it is apparent that a given weight of sand would through increase in grain size result in an increased volume.

It was necessary then to remodel the corebox to accommodate this increase in volume of sand. Our judgment indicated that by increasing the height by ¾ inch, we would have ample capacity for any mixture. The new corebox therefore is 16 x

3 x 2 1/16-inch in height, producing a core after ramming 16 x 2 x 1-inch as in the previous experiment.

The weighed amount of sand is passed through the sliding riddle into the corebox. A riddle limited to one direction of motion will heap sand higher in the middle than at the ends, and to secure an even distribution in the box, it is necessary to move excess sand in the middle to make up the shortage at the ends. Pressure applied during such an operation would pack the sand in the middle, resulting in a core which after ramming would be denser in the center than at the ends. To eliminate this possibility, a strike with a V shaped edge was provided and constructed so that it had to slide on the top of the box, preventing downward pressure. Since volumes of sand will vary, as already explained, a uniform distribution of material in the box is secured by passing a series of strikes, consecutively deeper by 1/16-inch, back and forth until the level of the sand is the same in all sections of the corebox. The sand is then rammed and tested as before.

Table XIX

	Definite volume		Definite weight			
Batch	Clay (qts.)	Moisture per cent	Bond	Moisture	Weight taken	Bond
1.....	5	4.95	96.5	4.90	1050	88.5
2.....	8	5.05	98.0	4.71	1045	120.9
3.....	12	3.55	101.5	3.81	1040	152.3
4.....	15	3.40	107.3	3.35	1035	222.4
5.....	20	2.84	239.7	3.00	1030	252.6
7.....	25	3.85	119.6	3.50	1035	277.9

The bond values of all preceding mixtures were determined, and a comparison of the old with the new values is made in Table XIX and the solid line in Fig. 10.

The table and the graph show a vastly more probable set of results than those obtained by any other method, and it is our belief that this method approaches the ideal more closely than any method worked out so far.

We are confident that it is a reliable test, but in trusting that our work in the future will prove this to be true, we do so with considerable assurance.

This method has been followed by the Sivyer Steel Casting

Co. for several months, and nothing has happened to indicate that it will prove to be unreliable, as were its predecessors.

The writer has believed for a long time that just as many defects may be traced to improper facing as to any other cause. By improper facing he does not necessarily mean faulty materials nor poorly balanced mixtures. The greatest difficulty is in the lack of uniformity from day to day or week to week. This lack of uniformity may be due to the variation in materials, the mills, or the operators.

Simple and reliable tests which check the facing will, if used consistently, warn of trouble to come before it actually develops. Most of us, if warned, are able to correct the existing condition and prevent the trouble.

Though this paper is dry, and perhaps technical, it has been prepared for those who desire control of their facing. The work has been difficult, and has consumed much of the writer's time, but the actual test as now worked out is simple, and as stated, deemed reliable.

Acknowledgment is hereby made to the Electric Steel Co., Chicago; the Fort Pitt Steel Casting Co., McKeesport, Pa.; the Lebanon Steel Foundry, Lebanon, Pa.; the Michigan Steel Casting Co., Detroit; and the Sivyer Steel Casting Co., Milwaukee, for the co-operation which made this investigation possible. These companies are the members of The Electric Steel Founders Research group which has financed the work, thus providing the writer with the equipment, labor and material necessary.

Discussion—Establishing a Method for Testing Green Bonded Strength

MR. H. B. HANLEY.—I think in view of the great enthusiasm shown at this meeting, it would be greatly beneficial to all those present to have Mr. Doty tell us a few of the features relative to the determination of green bonded strength, and especially so as to emphasize the degree of accuracy of that method as he has found it to be.

MR. R. J. DOTY.—The paper as prepared is really a history of our attempts to establish a method which is reliable. The idea is not new; we started off with a method familiar to all of you, of having a little core box, filling it with sand, ramming it to a given consistency and then pushing it off the end of a glass plate slowly and measuring or weighing the overhanging section. Early in the tests it looked good to us, but we got a little bit suspicious, and so we started to see just how reliable it was. We found it was not reliable, that we could not get two bars from the same batch of sand to check and could not get bars from two batches made exactly the same way to check, and so we went to work to see if we could not perfect a method whereby we could get those checks which were within reason. The work covered a period of nearly two years and was a much larger proposition than we imagined when we started.

MR. R. F. HARRINGTON.—It seems to me that Mr. Doty has made a wonderfully valuable contribution to our literature on molding sands and their testing. Certain things struck me particularly forcibly in his investigation. Few of us could picture, a few years ago, the necessity of accurately testing our molding sand beats. Mr. Doty has not only found it worth while to inaugurate a test that is accurate, but he has found it much worth while to inaugurate means whereby the quality of his mixing through the shop is equally as accurate,

and it seems to me that he has found a valuable note that the manufacturer can well take into consideration—the necessity of paying stricter attention than ever to the details of mixing operations.

MR. L. K. BROWN.—This investigation takes me back to 20 years ago when, with the assistance of Dr. Moldenke, I carried on quite a number of investigations and experiments at my own expense, found that the time was not opportune for standardizing molding sands, because so many foundrymen had different opinions regarding what should be. It is a pleasure to see this work now being carried on as it is, and I want to assure you I shall be glad to render whatever assistance I can.

A MEMBER.—I would like to ask Mr. Doty how often these tests are taken? Is each batch tested separately, or do you take one test a day or take them once or twice a day?

MR. R. J. DOTY.—The tests are being made morning and afternoon. One test is made from a batch taken at random; another test is made from an average taken from the different sand bins. In addition, aside from my regular practice of morning and afternoon tests, we do considerable work in testing the sand throughout the day, and carry on a considerable investigation. As a matter of fact we plot and record the permeability, grain size, moisture and green bonded strength of our sands in the morning and in the afternoon. That is carried on a chart kept up to date, and we have it there to be compared day by day, week by week, and month by month, and we can go back a year. That is molding sand as prepared for the molders. We test core sands too.

MR. J. M. ROBERTSON.—I would like to ask Mr. Doty what he considers moisture in his molding and core sand?

MR. R. J. DOTY.—That is a hard question to answer. I can only tell you what we find; I cannot tell you what I think it should be. In our facing sands, our average moisture content for a month would be about 4½ per cent. Average moisture does not mean much because it might be 4 per cent part of the month, 5 per cent part of the month, et cetera, but during the month of May for green sand molding the lowest figure we touched on moisture was 4.42, and the highest was 4.56.

MR. GRAY.—I would like to ask how long it takes to conduct a green bond test such as you describe?

MR. R. J. DOTY.—It takes us about 1½ hours to make tests for all four qualities. They are run simultaneously. The thing that makes the hour and half necessary is the moisture test. We combine that moisture test with the green bond, eliminating one operation, while we are getting the moisture from our sample we are also getting the amount of moisture in that particular box of sand.

MR. F. B. SWEET.—I would like to ask how often you use your sand over in the day's run? We have a continuous process, and our sand is used over about every 20 minutes, comes back in the shake-out from the molding machine. We use our sand maybe much quicker than you would, and I do not know whether it would be possible to take tests on sand that is used over every 20 minutes.

MR. DOTY.—Our heap sand is used over and over during the day, but in the preparation of our facings, we use a large percentage of the used-over heap sand. That sand is allowed to stand until the following day before transferring it to the mills, because we are great believers in using cold sand in the preparation of facing. I mean sand in which the casting temperature has entirely disappeared. We check our heap sand occasionally for the condition of the heap sand is very important in the production of good castings, but we feel that if we can control our facing sand against which our metal comes, and are fairly accurate in the control of our heap sand, we get better results

MR. R. F. HARRINGTON.—It seems to me that in the case Mr. Sweet mentions, Mr. Doty's application can still be made and that it would not take but a few minutes to sample this heap that comes on through and is going to be used over again every 20 minutes, and would give very definitely some warning of any trouble that might crop up in a day or two. I cannot see how it would be possible to apply Mr. Doty's scheme to prevent a few bad castings in the next hour or two, but I think it is definitely possible to eliminate and take care of any very serious trouble before it happens.

The Preparation of Steel Foundry Sands

By S. H. Cleland, Chicago

The constituency of the best molding sands suitable for use in steel foundries has been expounded so frequently, particularly during the past ten years, that no foundryman need be without information on this important subject. Briefly, they consist of combinations of a tempering agent, rounded grains of approximately pure silica of uniform diameter and extra plastic, highly refractory clay. The size of the grains and the clay content will depend upon the character of the mold; whether light, medium or heavy weight castings are to be produced.

Sands compounded, as specified above, provided they be properly prepared would aid essentially in producing the great objective—sound castings of improved appearance. Sufficient vent area would be maintained to permit of a proper evacuation of the steam and gases, and there would be little, if any, fusion on the surface of or in the sand body. Unfortunately, these desirable results, unquestionably possible of attainment, are far from common in American practice. This is due to two primary causes:

First: Incorrect methods of sand preparation,

Second: Use of unsuitable molding sand components.

It is with the first of these causes that this paper treats particularly, although not exclusively.

Given the best silica sand and clay obtainable, their value can be, and frequently is, thoroughly neutralized through the application of faulty blending methods.

Ordinary mixing such as is accomplished in paddle type and centrifugal mixers, pug mills and reciprocating and rotating screens, is of positive detriment. These contrivances serve merely to deposit the binder among the refractory grains. So de-

posited, its full efficiency is not developed and the vent area is seriously clogged. What must be used is a mechanical method by which sufficient pressure is exerted to spread the clay evenly and thinly over the grains. A continuity of bond is thus effected with the resultant extreme toughness of the entire mass. Obviously, too, by thinning out the clay, porosity is increased.

Developed Sand Mixing Apparatus

Until well into the present century, pan grinders were regarded as the most efficient pieces of machinery for the purpose. Within recent years, however, the industry has called for special equipment for the preparation of steel foundry sands and, due to this constant demand, there has been perfected mixing or mulling apparatus, which is especially adapted to do the work correctly. Great care must be exercised in the use of all types of equipment of this character in order to insure proper blending without developing crushing action.

Crushed silica grains take on a condition of angularity, that is, they are composed of flat surfaces that meet in sharp angles. Lack of uniformity in grain size is an accompanying evil. Angular grains rammed hard (common practice) interlock and permeability thereby decreases. This troublesome condition is intensified by the finer particles finding lodgment in the spaces between the coarser ones. Reduction of grain size increases the surface area necessitating the use of more clay, and for the same reason, more tempering agent must be added to insure moldability. In producing green sand facing the agglomeration described, trouble breeding though it is, becomes more so when blended with varying quantities of heap sand always loaded with deleterious matter. The general effect is that the molds become dense to the point of being impervious to gases and steam, and hard to the point of unrest for the metal. The thin sections of the grains, particularly those on the surface of the mold, fuse readily, and fusion once initiated is likely to engulf the whole grain and to progress to contact grains or binder. The clay, too often fusible at molten steel temperatures, suffers in the general destructive tendencies. In these circumstances, not exaggerated but common, is it any wonder then that sound, sight-

ly castings are the exception and not the rule, when improperly prepared sand is used?

The reverse of the condition just described—maximum efficiency of new material added, together with maximum permeability—is made entirely possible through the advent of the specially designed equipment mentioned heretofore. The feature of transcendent importance, insofar as the special mixing units are concerned, is the adjustment by which mullers can be raised or lowered through set screws and locknuts located on the headstock. Change in mixtures may be regulated by changes in muller position. With the muller operated close to the pan floor the product become exceedingly tough. The more the mullers are raised the less intensive is the mixing action. They should never be so close to the floor that only individual grains intervene. In that event the pressure would be sufficient to crush them.

Proper Water Content Necessary for Best Results

Lack of uniformity in the moisture content of molding sands leads to difficulties about which all foundrymen are fully acquainted. The custom of applying the tempering agent by means of a pail, throwing it into the mixing chamber in quantities inaccurately measured, and trusting to luck that the result will be gratifying, is open to severe criticism. Europeans consider the operation of so much importance that many of them use elaborate processes to dry their sands and then spray in the moisture in a predetermined ratio. Similar care in manipulating other processes may explain why some steel castings made in Europe are marvelous in respect to surface finish.

Each clay needs its particular amount of moisture to develop its full bonding power. So, when blended with silica grains, the resultant molding sand requirement of moisture will depend upon the character and quantity of clay present. The precise amount to apply may be determined by duplicating the method employed by the late R. L. Lindstrom,* to obtain accurate information relative to the bond value of clays. Concisely, it consists of pushing lengthwise, off a glass plate, green sand

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cores of the dimensions 12 x 1 x 1 inch. The length of the portion of the bar breaking off indicates the bond strength of the mixture. Altering the amount of water in each batch of sand tested will soon bring out the desired data. At first as the moisture content increases the cores will get stronger; ultimately, a decline will set in. The proportion that made the strongest cores will establish the practice that will yield the most benefit. The tempering agent should be added to the sand during the mulling operation. To facilitate distribution it may be sprayed in from a pipe placed horizontally inside the pan rim and so shaped as to follow the contour of the rim. A line of small holes perforating the bottom and side of the pipe will give the desired spraying effect. The feed should be by gravity from a tank easy of access and so graduated as to permit measurement of its contents.

Loading methods, heretofore contributing importantly toward the inaccuracies that once marked general procedure, and are still doing so in many foundries, have been rescued from their lack of excellence by the introduction of bucket loaders built in simulation of the so-called skip hoists used in conjunction with concrete mixers. The buckets serve as measuring boxes and may be divided into compartments by removable partitions. The dimensions of the compartments may be regulated so that when they are full the correct proportion of each ingredient is contained therein. The count method, using shovel and wheelbarrow, is too unreliable to be tolerated. Incidentally, bucket loaders permit of an increase in sand production. During the time one charge is being blended another may be prepared ready to feed into the machine as soon as the pan is empty. Furthermore, all of the ingredients are dumped into the mixer at practically the same time, so that all of them receive the same degree of mixing. Power to drive the loader may be taken from the main driving shaft of the mixer or an air hoist may be used to elevate the bucket.

Proper supervision in the sand mixing department is of great importance. Putting an inexperienced laborer in charge of sand mixing operations does not promote the production of

fine castings. He and his assistants do not realize the importance of absolute precision in compounding the various mixtures and, particularly when relying on the count system, they are likely to commit serious errors. Supervision should be delegated to a higher order of intelligence. Then concordant results may be expected from a section of the foundry that now receives too little consideration. The mixing department of a foundry with which the author is familiar is supervised by one of the members of the firm conducting the business. Much of his time is spent in testing mixed sands and in watching mill operations. He gives the molders good sand and they, as a rule, give him splendid looking castings. The product of that foundry has a national reputation.

Use of Old Sand Versus New Sand for Facings

Considering how extensively heap sand is employed as a component of facing sand, it would be a bold person, indeed, who would condemn the practice. The only argument, however, that can justify its use is based on economy. And it is a mooted question whether or not, with a full accounting rendered, such a premise could be sustained. Following is the situation merely as the author sees it: Continuous re-heating of silica grains and clay at molten steel temperatures induces radical changes that effect the heat resisting and venting qualities of the resultant conglomeration. Microscopical examination will show that it contains fine particles of fused and unfused clay, small grains of sand, large grains of fused and unfused sand and combinations of all of them. If any binder other than clay be part of the facing sand, unburned particles of it also will be found in the heap. Contemplation of that "mess" compounded with even the best of new sand may explain the preference of many for coarse grain sands. There are superintendents who boast of the large quantities, 60, 70, 80 and even as high as 90 per cent, of heap sand they can "get away with." As the proportion increases the disastrous tendencies increase, particularly when it becomes necessary to use an extra quantity of clay and perhaps some vegetable paste binder to develop the moldable quality absent

on account of the predominance of weak heap sand. To blend the mixture in a poorly designed old style pan grinder would further complicate the matter as would the use of sands of angular grain instead of those of rounded contour. Poor, close facing sand never has developed into good, open backing sand, so, is it any wonder that religious venting in many shops is deemed an operation of paramount importance. Assuming the foregoing to be a correct statement of conditions, doesn't it seem that many of the diseases to which steel castings are heir might be attributed to manufacturing facing sands in the accustomed manner?

A proper all-new-sand facing sand would consist of a combination of rounded grains of approximately pure silica of uniform diameter, a small amount of extra plastic, approximately pure refractory clay, and only enough moisture to develop the ultimate strength of the clay. Demand for the sand and clay ingredients has instituted researches for them and they are becoming obtainable at sources not too distant from the steel foundry centers to make their use prohibitive. The clay should be flour fine as it will then mix with the sand speedily and be susceptible of assuming the shape of a thin coating. Lump clay spells inefficiency in several directions and will find no favor with those who aspire to improve their product. Rounded grains of sand will not be disintegrated in the muller machine, and when blended with the clay of the character mentioned, no amount of ramming will cause them to lie so close that the vent space will be insufficient to permit the escape of steam and gases. The clay and sand not being fusible under 2900 degrees Fahr. will put up a very tenacious resistance to molten steel, in fact, in a single application of it they will be very slightly affected. The heap sand will therefore be strong and open, thus insuring proper condition throughout the mold. Some advantages would be fewer blows, cuts, scabs, drops, less patching, less nailing, stronger molds, less expense in blending, mulling and cleaning departments, less supervision, fewer rejects, fewer returns.

Greater consumption of new sand? Yes, initially, but if the

rich waste sand be put through a satisfactory, available reclaiming process, more than 80 per cent of it should find its way back from where it started to help refute the old-sand economy argument. Steel castings, smooth and unblemished, due to their superior strength and relative lightness would replace big tonnages of gray iron and malleable castings in the automobile and many other industries. By recourse to the best possible practice, part of which has been outlined above, the requisite surface conditions could be achieved. In other words, finer finish would develop broader markets and broader markets would mean greater profits—greater satisfaction.

Heap sand is the "poor orphan" of the foundry. Usually it receives an indefinite amount of water, is cut over carelessly by laborers and is then asked to perform almost as importantly as facing sand. No portion is as strong as it should be, due to the unequal distribution of moisture. Too much moisture in one place and too little in another means weakness everywhere. In this condition, how can backing sand knit with the facing sand, support it sufficiently to carry the cope, and particularly large hanging bodies of sand in the cope, or contend with casting strains? Gases that go through good facing sand, rightly prepared and encounter wet spots in backing sand, are disposed to return in the direction from whence they came, and finally find lodgment in the metal or blow off sections of the face of the mold that for one reason or another may be impervious to them. To be fit to perform its part, heap sand should be as carefully prepared as facing sand, that is, it should be put through a muller and receive the exact amount of moisture that will develop its maximum efficiency.

Natural and Artificial Binders

Dense, incompletely baked dry sand molds conduce to a large scrap heap. A possible remedy may be discovered in the following statement: Strong, plastic clays may have their bond value increased markedly by chemical treatment. A small quantity of clay so treated, preferably by the shipper, thoroughly disseminated throughout a rounded grain silica component, would invest an all-new-sand facing, and in a lesser degree

the backing sand, with such an abundance of strength and permeability that many light heavyweight castings now made in dry sand could be produced in green sand. When, however, the limit is reached and dry sand molds become a necessity, the exceptional porosity would contribute to complete drying of the molds—the heated air in the oven could enter the sand readily to do its work and the steam and gases could evacuate without hindrance. Binders other than clay, frequently used to help the mold withstand the attack of large bodies of molten metal, need thorough drying to function properly, and they would be more likely to get it by the method described than by following beaten paths.

Natural steel sands, used extensively in the eastern states perform only fairly well in comparison with synthetic sands correctly compounded. Inferior grades predominate and represent the extreme of unsatisfactory mixtures. The clay content is under no control and is usually present in large, moist lumps, difficult to disseminate by any blending method. A combination of rounded and angular grains make up the silica component and these vary in size too greatly to insure the necessary porosity. Already, a reaction has set in against the so-called strong sand and the prediction is ventured that they will eventually be superseded by synthetic sands compounded either by producers of the ingredients or the users thereof.

The efficiency of any binder repends upon its ability to collect at the contact points of the sand grains. Those in general use in steel foundries are farinaceous products, coal tar compounds, sulphite pitch (paper mill waste), molasses and core oil. Farinaceous binders (corn and wheat products) are classed as paste binders and tend to collect in small masses on the face of sand grains. The portion so located performs no function except to clog the pore space. To develop their full value and to reduce their vent decreasing propensity, sands in which they are incorporated should be blended in a muller machine; one that will, by pressure and rolling action, spread the binder thinly over the sand grains. The desired strength will thus be created with the least possible amount of binder. Great

care must be used in drying as these binders char completely at slightly over 410 degrees Fahr. Also, sand should be tempered sparingly to prevent distortion of cores or molds during the drying process.

Coal tar pitch compounds, in common with all dry binders, are deposited mainly on the surface of the sand grains. Under the influence of heat they melt and flow over the grains and much of them collect at the contact points and harden there as they cool. Dry sand molds and cores in which pitch compound is used as a binder should be tempered liberally and baked quickly at relatively high temperatures (400 degrees to 600 degrees Fahr.). All of the pitch should melt before the mixture has left the sand as it will not adhere properly to dry sand. Cores and molds will not change shape while drying and they will bear up wonderfully well under all but the highest temperatures known to the industry. Fineness is essential; distribution is thereby facilitated and the melting process accelerated. Coal tar pitch carries about 50 per cent of volatile matter. If, in drying, this be entirely driven off, maximum strength will be developed and castings will be cleaner and smoother.

Molasses and sulphite pitch, diluted with varying quantities of water are used principally as tempering agents. As such, they materially aid other binders to function more efficiently. Almost all sands used in steel foundries for producing cores and molds are bonded, that is, they contain clay. Sulphite pitch contains tannin and this element strengthens clay remarkably. For this reason and because it is more uniform than molasses, and will not deteriorate through fermentation, when diluted as will molasses, sulphite pitch is preferred by the majority of steel founders. Distribution in bonded sands is accomplished only in machines which, by pressure, force the compound into every part of the sand mixture.

Core oil is particularly useful when light weight metal is to be cast. Rounded grain sands free of bond will accept core oil easily and in this combination the greatest possible strength is obtainable. The maximum strength of oil sand cores is maintained in the mold until molten metal touches them. Their

strength is then immediately and totally dissipated. This feature is made use of when shrinkage of metal would be likely to check castings poured against cores that would remain hard beyond the psychological moment. Bonded sands are used in combination with oil when green strength is required, and to counteract the acute searching disposition of molten steel which manifests itself in a fused condition of the core surface of open sand cores with attendant bad results. Due to its viscosity, core oil enters bonded sand very reluctantly; the law of capillary attraction that aids in developing its full efficiency in unbonded sand is neutralized. A squeezing action is therefore compulsory to secure as nearly as possible the strength resulting from even distribution. An emulsion of oil and tempering agent reduces the viscosity of the oil and the mixture has more penetrating power than undiluted binder.

Buyers of steel castings are continually clamoring for better surface finish coupled with absolute soundness. The days of keen competition are here with a vengeance. Now and henceforth, improvements in practice will be compulsory upon those in the industry to enable them to obtain their share of business, without which success would not follow. This contribution is submitted with the hope that it may contain information that will prove helpful to steel foundrymen in their endeavors to meet the exigencies of the situation.

Discussion

R. F. HARRINGTON.—Mr. Koch says I am elected to say something on this subject. I did not hear the early part of this paper, but I can certainly concur with Mr. Cleland's opinion in regard to the mixing of sands and the efficiency of same by this mulling action. I think that in case of both gray iron and steel practice, that the mulling action does take the binding material, whether it be clay, whether it be loam or whether it be an artificial binder, and puts it around each grain of sand which, in the very doing of that, takes the binding material away from the open spaces and therefore away from the places

between the grains, and therefore allows better venting. In other words, I can conceive of a sand improperly mixed in which you would have your particles of clay filling up the places that you want void. I believe that the efficiency of the mulling operation is in that it takes these particles of clay or the binding material and puts them where you want them, around the grains of sand, and leaves a void so that your sand will properly vent.

H. B. TAYLOR.—Do I understand Mr. Cleland to say that he can coat every particle of sand as well as nature has done with strong natural sand?

S. H. CLELAND.—It can be done in a muller machine better than nature does it. As evidence of this I have only to call your attention to the fact that any natural molding sand treated in a muller machine for a few minutes will have its strength increased markedly. This is due to a better distribution of the bond than is provided by nature.

H. B. TAYLOR.—I am a sand shipper and I am talking simply from a layman's standpoint. Although I have been in this game 30 years, I know nothing about the practice of molding. Our method, as you all know from the sand salesman who visits you, is to pick up the sand in the hand, and rub it and look at it. That is all the preparation we do because that is all the preparing you foundrymen have asked us to do. We have at out banks men who are common ordinary laborers and who never saw a foundry and do not know what a foundry looks like, and I speak for all the sand shippers. It has been my impression from talks with steel foundrymen that the idea is to get a grain of sand angular. New Jersey has no angular sand, but Mr. Cleland will agree with me that there are quite a number of successful steel foundries doing good work in the East, so that the reason I was prompted to ask the question of Mr. Cleland, whether he thought that mulling process would coat each and every little particle of sand as well as the strong sand which he says in time will be eliminated, though we hope not from our standpoint. It is true that Mr. Cleland is familiar with our South Jersey strong sands. There is a most peculiar formation which nature has

made, laying in a confined district, along the Morris river, about 40 miles this side of Cape May, and the formation there is a layer of clay, a layer of sand, then another layer of clay and another layer of sand. In our primitive way of digging sand, we simply slice it down. Now in the spring of the year, when we have excessive rains and moisture, naturally those clay lumps will stick to the shovel. I wanted to ask that question and you have answered me that you think mulling will coat each and every particle of sand.

S. H. CLELAND.—And I think that synthetic sands can be developed that would have greater value than the natural sands. My experience with those strong sands, with the clay in those strong sands particularly, is that it is of average quality. By the dye adsorption test, which indicates bond value, it shows a strength of 3000. That is fair, but there are clays in New Jersey which have a dye adsorption number of 5000. Those clays may be, by chemical treatment, increased at least 100 per cent in bond value. It is easy to conceive that less clay of that character would be required to provide moldable quality than the clay natural to your strong sand. The less clay used the more chance the sand would have to vent properly.

H. B. TAYLOR.—Magnifying that statement somewhat by marbles, take two marbles and in between those points of contact, you would have to put clay in there; now which would fuse the quicker, the clay or the sand?

S. H. CLELAND.—The clays I have in mind are infusable at molten steel temperatures, they will not fuse under 3200 degrees Fahr.

H. B. TAYLOR.—The foundries are not using this clay The trouble is that there are only one or two men in this room who, if they are near the Amboys, would use those clays. It is fine, if you are going to get them way out West, to use those clays; I know where Missouri clay comes in in the East.

S. H. CLELAND.—I believe that the location of the clays would have little effect on the availability of them no matter where the foundry is located, for the reason that, by increasing the bond value of them through chemical treatment, so little of

them may be used that they could be transported to the big steel centers and not have the cost of the finished product prohibitive. Another thing about your strong sands—the amount of clay in them varies greatly and this lack of uniformity tends to increase the unknown quantities that keep foundrymen from obtaining continuous good results.

R. A. BULL.—It seems to me that possibly Mr. Cleland has in mind in answering Mr. Taylor's question, a better grade of clay, or perhaps Mr. Taylor had in mind a better distribution of clay through the sand, so there are really two angles to the same question. I want to ask Mr. Cleland where he can find that clay that will fuse at 3200 degrees.

S. H. CLELAND.—I have in mind a particular clay obtained in the Woodbridge, N. J., deposit, that is said by producers to have a fusion point of about 3200 degrees.

WILLIAM KRODELL.—It is interesting for me to come here and discuss the sands for molding and steel casting. While I am a brass founder, still I am making castings in nickel and I have great trouble in getting sand that will stand the heat. I have used Lumberton sands and I ran into the same trouble; it fuses. While I am using French sand, the price is too prohibitive, so I wonder if I could ask the question if silica and clay would be suitable for nickel castings?

S. H. CLELAND.—Yes sir, suitable clay and silica sand, compounded in a muller machine, the silica grains being of a size corresponding to the class of work you are doing, would enable you to cast nickel successfully.

R. F. HARRINGTON.—It seems to me that the big thing to get out of this paper, particularly from a personal viewpoint, is the fact that Mr. Cleland has emphasized the necessity of careful supervision. I personally believe that more castings are lost due to improper preparation of sand and improper sand to begin with, than any other one item, and I believe it all goes back to improper supervision. Well, we will go back to the sand producer; I was talking to Mr. Taylor and I told him that the day was coming, I thought, when they were going to put much more intelligent supervision at the sand banks so that we could be assured of a more uniform product, and then

we have to do our part in making our supervision of the mixing of those sands even more intelligent. I think that the big thing to get out of this paper is the fact that we are going to be successful insofar as we intensify that supervision of mixing, because we can have the best quality of material to do with, and unless we carefully supervise it to the minutest detail, our troubles are going to be many.

H. B. TAYLOR.—I have attended, I think this is the 28th convention, and it is the first time I have heard anything said about molding sands. I think it is one of the most important things, particularly from the sand shipper's standpoint, as Mr. Harrington has said, and he has visited a great many banks, I presume as many as any man in this audience, but there has been so little support given us sand shippers.

R. A. BULL.—May I say just a word to supplement what you said? I am glad to see this interest in this sand question. We do not want to see the thunder of the sand session stolen by this one, but I do want to urge everybody who has any interest in this question to attend that session Thursday morning. Mr. Taylor has truthfully made the statement just a few minutes ago that the men who produced sand have not any means of knowing what the foundrymen want because he squeezes it with his fist and that's all there is to it. He is perfectly right there. He is wrong, however, when he says there have not been any papers presented on this subject. There have been some in years past, and very good papers, but I think we are going to have a very healthy and helpful discussion Thursday, and I hope all who have any interest in this thing will be there.

W. KRODELL.—I have been in the foundry game about 30 years and I have found only about a dozen foundrymen who paid strict attention to mixing sand, and that was more or less in the lock foundries. There may have been a system for mixing sand for all classes of metals, aluminum bronze, dry sand for different classes of work, and I think as far as I know, the brass foundries in this country, the lock shops, are the only ones that ever put any effort into mixing sands. In the ordinary jobbing foundry, we pay no attention to it, we run out to a heap of sand, get a riddle full, put it on the floor and go ahead

and use it, and that is all the jobbing foundries are doing. I think it is a great thing if we discuss this matter and get more deeply into mixing sands for the different classes of work we do.

W. E. NACHTIGALL.—Will the speaker tell me what success he has had with green sand facing without fire clay, with nothing but a vegetable compound just to bind the aggregate?

S. H. CLELAND.—Would that vegetable compound be in the form of a farinaceous binder, corn or wheat?

W. E. NACHTIGALL.—Yes, generally wheat only.

S. H. CLELAND.—I believe, generally speaking, you would not have success. I have not had any experience with nor do I know of farinaceous binder being used for green sand molding work to the exclusion of clay. In my opinion it would not work successfully for the reason, as stated in the paper, that farinaceous binder chars absolutely at slightly over 400 degrees Fahr. The charring action begins at about 350 degrees Fahr., therefore the binder would be completely burned out before the metal had set and you would have disastrous results therefrom.

W. E. NACHTIGALL.—I asked that question because I have been using the green sand facing with a vegetable compound with excellent results. Now you did not mention that and that is why I asked the question. We used fire clay and found that fire clay burned into the casting, and we would either have to run them again or sand blast them more extensively than we do at the present time. When shaken out, the castings peel readily, leaving no sand burned in. That is the experience we have had without fire clay. The only fire clay we used was in coarse sand.

S. H. CLELAND.—Those castings were very light, weren't they?

W. E. NACHTIGALL.—Up to 500 or 600 pounds.

S. H. CLELAND.—I venture to say that the castings were of considerable area; the walls of them were not heavy. However, that is a new experience and it is very interesting despite the fact that the cost would be excessive due to the amount of binder that must be used and the high price of it; five or six times that of infusible clay that would not burn into the cast-

ings. It is common practice to use farinaceous binders in conjunction with clay producing what is known as air dried molds. In that respect they have great value, since they increase the strength of the molds and prevent the washing that might occur when the metal is hottest. Use has been made of oil and farinaceous binders in combination in parts of the mold where shrinkage was such that the vitrifying of clay would tend to cause checks in the casting. The effect of the use of the combination is that the burning up of it before the metal cools permits the mold to collapse thus allowing the casting to shrink properly—without cracking.

MR. DUNCAN.—I would like to ask how about using a binder which becomes a liquid?

S. H. CLELAND.—Under what conditions would it be used?

MR. DUNCAN.—After mixing the sand with water.

S. H. CLELAND.—It has been my experience that the binder you have mentioned is insoluble in water, therefore it would not reduce to a liquid. It has great value in certain classes of work, particularly in the class I mentioned a short time ago, that is, air dried molds.

MR. DUNCAN.—In green sand molding?

S. H. CLELAND.—Yes sir. There is a binder, however, which is entirely soluble in water, and when it is in that condition it more thoroughly impregnates the clay, and because it has tannin in it, it increases the value of the clay considerably.

MR. DUNCAN.—The reason I asked this question was because I heard this gentleman speaking of cutting out clay in green sand molding. I have been using green sand 15 years, and I find that I get the same results this gentleman does with a green sand binder.

S. H. CLELAND.—That is a recent application. We are on the verge of progress in steel foundry practice. Many things are going to occur in the next 10 years that will far transcend in importance anything that has gone before in the last 50 years. One of the things I have in mind is the compounding of silica and clay, the proper kind of clay, infusible at molten steel temperatures, preferably by the producer and furnished to the steel foundryman in that form. There is a movement already on

foot to do that. A great many of our steel foundrymen are not equipped to determine for themselves what does constitute a proper silica component and a proper clay component, and if that could be determined for them by reputable concerns and the material furnished, that would improve their practice, it would be a long step toward the aim that the steel foundryman strives for, sound castings of improved appearance.

G. MUNTZ.—When the grinders were first built, they were given to us, as Mr. Cleland said, by brick makers and other people who were used to mixing clay, but when they were first adapted to steel foundry use, the mullers were much lighter in weight than those being used today. Now we are in the dark for suitable molding mixtures. We have tried most everything from brickbats to old crucibles. Of course we have to crush these somehow, and the only way we could crush them was to make heavy rollers, and that accounts for the happening of heavy mullers and the pan grinders. Some of those are being used and some are not. We have been advocating the use of the pan grinder and still are, notwithstanding Mr. Cleland's argument. The reason for the superiority of the pan grinder resides in the fact that the pan revolves and through its tractive effort, the rollers revolve. Through that you get a difference in speed between the roller and the pan which creates that rubbing action which is entirely desirable to the production of good foundry sands. If you change your grinder into revolving mullers and a stationary pan, you only have one speed to contend with and that is the speed of your muller; in other words, you have divided your rubbing action in half by cutting out the movement of the pan. One of the main reasons also why the mullers were made to revolve and the pan to remain stationary, was to make it easier to get the sand out of the pan. Now those of us who use pan grinders know it is quite a job to get the sand out of an ordinary pan grinder; that is one of the main reasons why the stationary pan is in existence today. It has no superiority over the pan grinder except that one, but it is inferior as far as mixing is concerned.

S. H. CLELAND.—I am willing to agree that there is probably more slippage on the occasion you have mentioned;

however there is some slippage in the muller machine, due to the fact that not only the mullers revolve around the pan, but they turn on their own axes, and thus provide the slipping action that is necessary for incorporation of the various components of the steel sand mixture. The chief difficulty with the machine mentioned, the pan grinder, is that the silica content sometimes is crushed.

In experiments I made with a machine of that character it was shown that the silica content, which was not absolutely uniform as to grain size, was disintegrated to the point where the coarse grains were at least 50 per cent finer than they had been and the fine grains were increased more than 100 per cent finer and that is dangerous procedure from the standpoint of the permeability of the mold.

G. MUNTZ.—What you say Mr. Cleland, is perfectly true, but who is to blame for this? When we first built grinders I happened to be in the same boat with Mr. Cleland except that in our case we used to make a pan with 100-pound mullers and made those mullers corrugated in order to intensify this rubbing action.

We built those and everybody was happy. One day somebody thought, as I said before, of the grinding of brickbats, cobblestones and crucibles and said, "Can't you make those with heavier mullers?" Sure we can. I have seen specifications where on a 500-watt machine, they wanted 700 or 800 pound mullers. We have got to give them what they want; we can't argue with them.

R. F. HARRINGTON.—It seems to me that this argument is getting down to a basis of what you want to use the machine for, mixing molding sand or grinding brickbats. I do not think it is a question of the merit of the two machines at all, it is a question of what you want to do.

S. H. CLELAND.—It is true that steel foundrymen often request things about which they are not fully informed; if they had a thorough understanding of them, they would not make requests that would be obviously to their detriment. These things are working themselves out gradually, and I be-

lieve the so-called muller machines will be the vogue as they are rapidly becoming.

R. J. DOTY: I do not want to get in trouble, and I am very apt to, being a user of both types of machines. I have to be careful what I say. One point has been overlooked, in speaking of the grinding pan, I think it is misnamed, it is not a grinding pan. The so-called grinding pan serves us so well that I think I ought to point out one thing that occurs to me at this time.

One of the pans properly adjusted will not crush sand, because there is sufficient clearance allowed between the upper side of the muller and the side of the plate to accommodate the largest grain of sand. That same pan, not cared for, can develop into a grinding pan, but a well cared for pan allows clearance so that there is always a cushion of sand between the muller and the plate.

CHAIRMAN C. S. KOCH.—Has anybody any figures on what the change in the side of the grain is when used in a pan grinder or muller? That is the whole point of this argument, whether you do any grinding or not. We do not want to pulverize our sand.

Does a grinder pulverize and has anybody made any test to find out whether that is true or not?

G. MUNTZ.—You are doing it yourself in your own shop. When you reline your converter the pan you use to grind the gannister is the same one in which you mix your sand. That is where the mistake comes in; you cannot grind and mix in the same pan. If you set your pan for grinding silica rock it apparently will not give good results on molding sand. If you want to mix molding sand you have to have a grinder for your gannister and a mixer for your sand.

S. H. CLELAND.—I fear that Mr. Muntz has not a full appreciation of the muller machines. They are quickly adjustable and there is a type I have in mind which may be used as a grinder with the rolls resting right down on the pan floor, and used as a muller machine when the rollers are raised from the

pan floor. Therefore I agree with Mr. Doty in his statement that a machine which might be designated as a pan grinder may be used as a muller machine if the rolls are constructed so as to permit raising so that only a mulling action takes place.

I have seen some so-called pan grinders which not only have the rolls resting on the pan floor, but they are kept there by springs which force them to perform a grinding action.

Report of Joint Committee on Molding Sand Research

To The Members of The American Foundrymen's Association:

It would consume too much time to describe in great detail the various steps taken in laying the foundation for an exhaustive investigation of molding sands. The work was made possible through a decision by the directorate of the American Foundrymen's association to devote to such a purpose a fund at its disposal consisting chiefly of $2500 given by Messrs. Thomas and John Pangborn, of the Pangborn Corp., Hagerstown, Maryland, and $1000 given by the National Engineering Co., Chicago.

Realizing the great need for co-ordinating a thorough research into many phases of this fundamental foundry problem, it was decided to organize the investigation in an appropriate manner and to enlist the co-operation of the National Research Council through its engineering division. Correspondence and conferences brought about this desired co-operation, and the assistant secretary of the American Foundrymen's association was finally instructed to prepare as a preliminary step, a bibliography on molding sand, and one on refractories as a related subject of great importance. This was a considerable task, requiring months of unremitting labor. Literature on these subjects had never been completely listed. It was desirable first to study reports of all investigations that had been made and to correlate facts wherever possible, thus reaping all the advantage to be gained from the valuable work of independent investigation.

A study of the literature cited in the bibliography on molding sands emphasized important truths that had been apparent before. Standard methods of testing, although of fundamental importance, were entirely lacking. Each investigator had in most cases followed his own ideas as to ascertaining the bonding strength or cohesiveness; the fineness or characteristics as to size and shape of grain; the permeability or previousness, or the facility with which gases may vent themselves through a

mass of sand; and other important characteristics of molding sands. The methods so employed differed to such great extent that it was generally impossible to translate the result of one man's work in terms employed by another. Contradictory conclusions had resulted from differences in methods. Factors of great importance had in many cases been overlooked by those who in reporting their tests had not perceived in the materials with which they had experimented certain evidences which in slightly different materials of the same general class were distinctly visible. It was plain that practical foundry problems were in some cases wrongly attacked on the molding floor through deceptive laboratory tests; and that in many more cases the foundryman has had to depend on what is crudely termed a "hunch" in his use of molding sand. This is not said in derision of the foundryman but rather in his defense, for the so-called "hunches" have been the result of experience and are quite as reliable as laboratory work that does not have a thoroughly practical basis.

The completion of the bibliographies as at first planned made an organization meeting the next appropriate step to take. This was held in New York on Oct. 28, 1921. It was immediately preceded by invitations issued by the National Research Council to a large number of men who had been tentatively selected for membership on the joint committee because of their practical or theoretical knowledge of the subject and those directly related thereto. The response was gratifying and indicative of the interest the matter holds for foundrymen, metallurgists, geologists, and others who can contribute information.

The joint committee as a body held its first meeting in New York, Dec. 9, 1921. Such progress as has been made, barring the general planning of the work, has, therefore, been the result of six months' organized effort.

An executive committee was selected. The executive body was of small enough size to function satisfactorily as a co-ordinating medium and to exercise direct power in a more effective way than is possible with a large committee difficult to get together for conference. This executive committee selected those who should comprise a sub-committee on methods of tests;

also one on reclamation. Subsequently another sub-committee was formed on geological surveys. These make up the present total complement of sub-committees. That on tests is headed by H. B. Hanley; that on reclamation by Fred L. Wolf; and that on geological surveys by Dr. H. Reis. Henry A. Carpenter, of Providence, R. I., was the original chairman of the sub-committee on reclamation. His greatly lamented decease followed soon after that of R. S. Lindstrom, of Montreal. Both of these gentlemen were highly valued and greatly interested committee members.

The members of the joint committee are now 40 in number. Their varied activities directly and indirectly related to the study of molding sands in the gray iron, malleable iron, steel and non-ferrous foundries, and to authoritative methods of testing and agencies for standardization, give definite promise that no important detail of the investigation will be deliberately slighted. In the following list it will be seen that there are seven representatives from the bureaus and technical departments of the United States government; one from a Canadian government department; and three gentlemen officially representing the American Society for Testing Materials:

JOINT COMMITTEE ON MOLDING SAND RESEARCH ORGANIZED BY THE AMERICAN FOUNDRYMEN'S ASSOCIATION AND THE NATIONAL RESEARCH COUNCIL

(R. A. BULL, *Chairman;* W. R. BEAN, *Vice-Chairman;* R. E. KENNEDY, *Secretary*).

Mr. Robert J. Anderson, metallurgist, United State bureau of mines, experiment station, Pittsburgh.
Mr. W. R. Bean, president, American Foundrymen's association, Eastern Malleable Iron Co., Naugatuck, Conn.
Mr. George A. Bole, physical chemist, United States bureau of mines, mining experiment station, Columbus, O.
Mr. R. A. Bull, research director, 639 Diversey parkway, Chicago.
Dr. Geo. K. Burgess, chief, division of metallurgy, United States bureau of standards, Washington.
Mr. J. A. Capp, chief, testing laboratories, General Electric Co, Schenectady, N. Y.
Mr. G. H. Clamer, vice president and secretary, Ajax Metal Co., Philadelphia.
Mr. L. H. Cole, mining engineer, department of mines, Canada, Ottawa, Ont.
Mr. J. C. Davis, fourth vice president, American Steel Foundries, McCormick building, Chicago.
Mr. R. J. Doty, vice president and works manager, Sivyer Steel Casting Co., Milwaukee.

Mr. George K. Elliott, chief chemist and metallurgist, The Lunkenheimer Co., Cincinnati.
Mr. John E. Galvin, president The Ohio Steel Foundry Co., Lima, O.
Dr. M. I. Goldman, geologist, United States geological survey, Washington.
Mr. Alfred E. Hammer, Malleable Iron Fittings Co., Branford, Conn.
Mr. Henry B. Hanley, metallurgist and chemist, 107 Ocean avenue, New London, Conn.
Mr. R. F. Harrington, chemist and metallurgist, Hunt-Spiller Mfg. Corp., Boston.
Mr. H. W. Highriter, assistant research engineer, Eastern Malleable Iron Co., Naugatuck, Conn.
Dr. W. O. Hotchkiss, chief, state geological survey, Madison, Wis.
Mr. Jesse L. Jones, metallurgist, Westinghouse Electric and Mfg. Co, East Pittsburgh, Pa.
Mr. C. P. Karr, United States bureau of standards, Washington.
Mr. R. E. Kennedy, assistant secretary, American Foundrymen's Association, 909 W. California street, Urbana, Ill.
Mr. H. M. Lane, president, the H. M. Lane Co., Owen building, Detroit.
Mr. J. Spotts McDowell, Harbison-Walker Refractories Co., Farmers Bank building, Pittsburgh.
Mr. P. E. McKinney, United States naval gun factory, Washington navy yard. Washington.
Mr. M. M. Marcus, vice president, Rhode Island Malleable Iron Works, Hill's Grove, R. I.
Dr. Richard Moldenke, consulting metallurgist, Watchung, N. J.
Prof. Cullen W. Parmelee, ceramic engineering department, University of Illinois, Urbana, Ill.
Mr. J. C. Pearson, chief, cement division, United States bureau of standards, Washington.
Mr. John Ploehn, superintendent, French & Hecht Co., Davenport, Ia.
Mr. Ross C. Purdy, Ohio State university, Columbus, O.
Mr. J. I. Reid, operating manager, Canadian Steel Foundries, Ltd., Montreal, Que.
Dr. H. Ries, chief, department of geology, Cornell University, Ithaca, N. Y.
Mr. W. M. Saunders, Saunders & Franklin, chemists, 184 Whittier avenue, Providence, R. I.
Mr. Homer P. Staley, Metal and Thermit Corp., 120 Broadway, New York city.
Mr. J. D. Stoddard, Detroit Testing Laboratory, Detroit.
Dr. R. W. Stone, state geological survey, Harrisburg, Pa.
Mr. Bradley Stoughton, consulting engineer, 10 East 44th street, New York city.
Mr. Enrique Touceda, consulting engineer, American Malleable Castings Association, 943 Broadway, Albany, N. Y.
Mr. DeGray White, Niles-Bement-Pond Co., Plainfield, N. J.
Mr. Fred L. Wolf, technical superintendent, The Ohio Brass Co., Mansfield, O.

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R. E. Kennedy, Secretary ex-officio
W. R. Bean
G. K. Burgess
H. B. Hanley
Jesse L. Jones
H. Ries

Bradley Stoughton
Fred L. Wolf

SUBCOMMITTEE ON TESTS

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R. E. Kennedy, Secretary ex-officio
G. K. Burgess
R. J. Doty
G. K. Elliott
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M. M. Marcus
DeGray White

Desiring the co-operation of sand producers when such co-operation would aid in the prosecution of the work the joint committee recently decided to form an advisory committee of such producers; and for the more practical working of such a body, to ask the five groups of sand producers, which seem to classify themselves from a geographical standpoint, each to name advisory representatives. It develops that one of these groups has no feasible method by which to select a representative, being made up chiefly of a large number of very small producers taking little interest in such a matter. On the other hand, one group of limited size geographically but including producers who do a large business, desired representation by two men. These problems, as yet, have acquired no importance because of the lack of benefit that would have accrued thus far by organizing this advisory body. There have been no matters that could usefully have been referred to these gentlemen for an opinion from a producing standpoint. It may be found

advisable soon to secure their co-operation in more important ways than by the securing of samples of sand in which there has been courteous disposition to render aid.

The preliminary consideration of the research showed the necessity for developing standard methods of tests before much else could be intelligently done. This threw the initial burden on Mr. Hanley's subcommittee, which has been responsible for nearly all that has been accomplished to date. Progress in this matter has been rapid, considering the difficulty of some of the problems involved and the fact that all men taking part in this investigation have heavy demands upon their time. It is now confidently believed that certain methods that have been perfected in almost every detail can be announced in the near future as reliable means of comparison. As soon as it may consistently be done after verification of these methods by those scientifically interested in molding sands, steps will be taken to cause their complete description, authoritative adoption, and extensive publication. Many phases of this molding sand research can then be undertaken permitting numerous agencies that have expressed a willingness to help to be put to excellent use.

The joint committee has felt highly gratified to receive many invitations to utilize facilities for this purpose tendered by many agencies and corporations, which fact guarantees unselfish co-operation.

An instance of the co-operative spirit which will be of invaluable benefit is found in the description of the results of the reclamation research conducted by the American Steel Foundries, courteously placed at the disposal of the joint committee and already given considerable publicity. The subcommittee on reclamation has before it a very large problem and like the other subcommittees, is extremely desirous of securing every item of information relating to the subject. The reclaiming of molding sand does not have for some foundrymen the significance it has for others who are not fortunately located close to deposits of suitable sand that are being worked. In the campaign for the elimination of waste and the conservation of materials which should be aggressively and continuously

carried on by every foundry, the reclamation of molding sand holds a very prominent place when we recall that in 1920 upward of $7,500,000 were expended by foundrymen for new molding sand.

Work by a subcommittee on geological surveys was considered advisable because of knowledge that some very satisfactory deposits of molding sands which have been worked for years are deteriorating while others are becoming seriously depleted. A factor of equal importance was the excessive freight charges that are being paid by foundrymen compelled to get their sand from a long distance. It is believed that there must be many satisfactory deposits of molding sands now undeveloped concerning which valuable information could be acquired that would result in their utilization. Dr. Ries, chairman of the subcommittee delegated to pursue this matter, has received much encouragement in the form of promises to cooperate from many state geologists. Active surveys are being planned in a way that will co-ordinate the entire proposition.

The chairman of each subcommittee will personally present a report to you indicating what it is hoped may be accomplished so far as may be seen now. It should be kept in mind that those who have consented gratuitously to give their time to this joint research are without exception very busy men; and that the prosecution of the investigation must be subordinated to many other things. I know that in some cases much effort has been expended in this work after regular office hours. An extended period may be required to clarify many things now obscure, of vital interest to the users and producers of molding sand. It is hoped that foundrymen generally will appreciate this, and that there may be no future stoppage of the work because of lack of funds with which to carry on.

The fund originally put at our disposal amounted to $4,321.20. Of this, $2522.93 has been expended. Of the latter sum, $1200.00 has been paid the assistant secretary of the A. F. A., who is ex-officio secretary of the joint committee. Most of this amount was for that part of Mr. Kennedy's time given exclusively for months to the preparation of the bibliographies. Expenditures go through the hands of treasurer of the A. F.

A. in the manner that applies to all association disbursements. The joint committee, as such, has no bank account. The balance now in this research fund amounts to $1798.27.

The present occasion offers a suitable opportunity for stressing one thing that it is desired to emphasize particularly. I have heard comments made that indicate an indifferent appreciation by some foundrymen and sand producers of the value of laboratory methods of testing sand. No greater mistake can be made than to follow such a policy in efforts to get at the bottom of molding sand troubles. The foundry foreman who says he has not had such troubles places himself in one of three classes. His experience has been restricted, or he has a poor memory, or he doesn't recognize molding sand troubles when they exist. I think all of us, as we acquire experience, feel uncertain to more extent than we did formerly, regarding the root of some molding sand evils. It is the job of this joint research, with the aid of all who can possibly help, to try to clarify these things.

At a foundrymen's meeting not long ago I heard two men, both of long experience with molding sand, sharply disagree on the relative values of coarse and finely divided clay in molding sand. Each based his opinion on superficial observation on the foundry floor. One of them told me that squeezing such sand in the fist of an expert was, in his opinion, a much better index of bond than any laboratory test that could be devised. This man had much respect for the general knowledge of molding sand possessed by his colleague who completely disagreed with him regarding the effect of coarse clay. Out of his own mouth the gentleman nullified his argument against laboratory testing.

I recently heard the statement made that it was a waste of effort to reclaim molding sand. An argument on that question would certainly be enlightening to the man who made this comment, could he meet an acquaintance of mine in the state of Washington who formerly secured, and may yet be buying, all his molding sand from Illinois producers.

The joint committee would not exhibit the proper, constructive spirit, if we attempted to ridicule any critics who

might feel this work to be potentially of little value, in details such as laboratory testing. I am convinced that very few experienced progressive foundrymen hold such an opinion. It should be kept in mind that this investigation is essentially a very practical proposition, undertaken primarily by those who are foundrymen first and foremost. Experienced representatives of this class of men constitute a large percentage of the committee membership. Such men can be trusted never to lose their practical viewpoint. They have no thought that laboratory tests of molding sand will displace the exercise of what is called "horse-sense." We need plenty of that, to be sure. But we also need what science offers, and that might be termed "man-sense." If we skillfully combine the two, the result should be acute "foundry-sense." When we acquire a greater amount of that, the effect will be gratifying in dollars and cents to those who make and use castings.

Respectfully submitted,

R. A. BULL, *Chairman.*

Report of Executive Committee Meeting

Sub-Committee on Geological Investigation of Molding Sands of the Committee on Molding Sand Research Appointed Under the American Foundryman's Association and National Research Council

It being well known that some of our important occurrences of molding sand are not by any means inexhaustible, the sub-committee on geological investigation was appointed to stimulate the search for further supplies in the different states, as well as in Canada.

Since such an investigation must needs cover a large territory, and involve more or less geological work, it seemed best to attack the problem through the medium of the various state geological surveys, and their co-operation was therefore solicited.

After preliminary correspondence, the chairman of your sub-committee held a conference with the state geologists at Amherst, Mass., at which time the matter was laid before them, and unanimously approved by them in principle, with a request that they be given exact information as to how they should proceed.

A circular letter was then prepared by the chairman of your sub-committee and submitted to the other members of the sub-committee for suggestions and criticisms. With these in hand a final circular letter was then composed and sent to the secretary of the State Geologist's Association for distribution to all of the state geologists. Copies were also sent to the several provincial geologists of Canada, and to the Canadian geological survey.

This letter contained: First, a brief statement of the importance of the molding sand industry; second, a description of the different types of sand required by the foundry industry, and need for developing additional resources; third, a list of the data that it seemed desirable and possible to

obtain in the field; fourth, method of taking sample, size and disposition of same; fifth, a short bibliography of papers on molding sand, in case any of the geologists desired to familiarize themselves more thoroughly with the subject. This circular which covers about nine typewritten pages, may seem rather detailed, but it endeavored to state all points on which the state geologists might desire information.

The communication emphasized the great importance of testing all samples in a uniform manner, and by standard methods to be recommended by the sub-committee on a standard test. This was done partly because it was recognized that a few of the state surveys were in a position to make their own tests. It was also stated that in the event of the survey's not being able to test their own samples, that the committee on sand investigation hoped to be able to make provision for having this done without extra cost to the surveys, which means that funds might have to be provided from some other sources.

Since this circular was distributed replies have come from several states direct to the chairman of your sub-committee. The replies on the whole are very encouraging, although some of the surveys have such a limited appropriation this year as to prevent their doing much.

To sum them up briefly:

The states of Maryland, Virginia, Alabama, and Florida will begin this summer to make a complete and independent investigation of their sand resources.

Ohio has already begun work on its sand deposits.

Pennsylvania, Tennessee, and New Jersey will collect samples for the committee to have tested.

Indiana is collecting information on its molding sand in connection with field work on coal and clay, and will be glad to co-operate with the sub-committee and supply all the information it has on the subject.

Oklahoma is much interested and hopes to carry on work in connection with regular field work. Texas will be glad to collect samples in the near future.

New York, I regret to state, has not indicated a desire to undertake any detailed investigation. The state geologist issued a brief pamphlet on Albany sand in 1916, which he feels "seems to him to fit the present condition in this state so far as it applies to true molding sand."

The several Canadian provinces have offered to co-operate in any way they can, and so far as their funds will permit.

Maine and California report no funds for the work.

Replies are being awaited from other states, so that this report is not to be considered final.

L. H. COLE,
M. I. GOLDMAN,
W. V. HOTCHKISS,
C. W. PARMELEE,
R. W. STONE,
H. RIES, *Chairman.*

Report of Progress

Subcommittee on Standard Methods of Testing Molding Sands of the Molding Sand Research Committee of the American Foundrymen's Association and the National Research Council

The subcommittee on standard tests has held three meetings since its organization. At the first meeting the members devoted their time to selecting the best tests known for examining molding sands. The following were selected as suitable for determining the various properties of molding sands: First, fineness test; second, bond tests; third, permeability test; fourth, water content test; fifth, thermal properties; sixth, rational analysis; seventh, chemical analysis; eighth, mineralogical analysis, and ninth, additional tests on various problems for subcommittee work.

At the second meeting we discussed the fineness test and bond tests. These were taken up first because it is generally agreed that they are the most important tests made on molding sands. The committee agreed on the method of procedure for making the fineness test and specified the use of the following sieve numbers:—6, 12, 20, 40, 70, 100, 140, 200, 270. The sieves must conform to the specifications of the U. S. bureau of standards. However, considerable work had to be done in order to determine the best deflocculator and the proper amount of same to be used in the test. These experiments were carried out and the results of the same reported at the next meeting.

Bond tests include cohesiveness test and dye adsorption test. We discussed these fully and agreed on methods of procedure, which were to be written up in detail by members of the committee.

At the third meeting the above mentioned tests, namely, the fineness and bond tests, were again fully discussed and finally found satisfactory to this committee, for recommendation to the executive committee, after corrections and improve-

ments in the details are made. Members have been engaged in rewriting the methods of procedure for these tests, which upon completion will be included in the minutes of the last meeting to be issued shortly.

Work was started on the chemical analysis, rational analysis and permeability test and plans are now being made for considerable experimental work to be carried out during the summer.

The U. S. bureau of standards has kindly co-operated with the committee and furnished us with a large number of tests on permeability, fineness and water content of molding sands. We have also received a number of offers of assistance from other sources and we will take advantage of them as soon as the work demands it.

G. K. BURGESS,
G. K. ELLIOTT,
RICHARD MOLDENKE,
W. M. SAUNDERS,
R. J. DOTY,
H. B. HANLEY, *Chairman.*

Discussion—Reports of Committees on Molding Sand Research

CHAIRMAN R. A. BULL.—I think it will be apparent to you from what Mr. Hanley has said, that a great deal of work has been done on this matter of tests. It might be appropriate to add just at this point the statement that to make the most essential tests will involve only a small sum of money for the preparation of the necessary apparatus. Of course that is a practical phase that will appeal to a lot of foundrymen who have not the means at their disposal for installing large laboratories. That will be apparent, of course, on the detailed descriptions which will follow later, after the definite, authoritative approval of these methods is voted upon by the main committee. The main committee consists of a large number of very practical foundrymen who know how to translate such tests into terms that mean something on the foundry floor, and you may be sure that these gentlemen will not overlook any point that has been reported to ourselves, in finally passing upon such methods. The authoritative adoption and wide distribution of them may be guaranteed by the fact that so many government agencies and other agencies of standardization are represented on the committee. Dr. Burgess, chief of the metallurgical division bureau of standards, is a member of the executive committee, of the committee on tests, and of course of the main committee, and is an extremely interested member of all these committees. The American Society for Testing Materials has three official representatives on the main committee on molding sand research.

The meeting might be opened now for a discussion, if you wish to present it, on the committee's report as a whole.

L. L. ANTHES.—Among other misfortunes, we have a foundry at Winnipeg, and one of our greatest problems there is molding sand. We have been buying it from different states north of the Mason-Dixon line; freight is too high to go below that; but notwithstanding that, we have sometimes to pay as

much as seven and eight dollars freight a ton on molding sand. I was very much interested in hearing about the grain of this sand; I think some of the sand we get is put through a coke mesh, not a sand mesh. I find tons of gravel half as big as your fist in a car of molding sand. There may be something of intrinsic value in Minnesota gravel, but we have not found it yet, and to pay seven or eight dollars a ton to bring it to Manitoba is not a pleasure. We have standardized pig iron and other things, and I think there ought to be a standard for molding sand, and pressure ought to be brought to bear on people to prevent their taking advantage of purchasers who are in the outlying districts and are absolutely dependent on them for sand.

Bond in Molding Sand

Another point brought up a while ago was on the bond of sand. I have seen cars of sand coming into the yard and told the foreman not to use that sand because there was no bond in it, because by taking it up and testing it in the hand, you can find practically no bond in it, and yet some of that sand has proved to be the best molding sand we have ever used. I am very much interested to find how far these investigations have gone. When they are carried through I trust they will be put before the regular foundrymen in a practical way so that we will know how and where to buy molding sand. I have seen a great deal of chemical research on molding sand, but that is not of much practical advantage to a foundryman who is not a chemist and generally does not employ one, and sometimes our testing laboratories are not as well posted on sand as they might be.

MR. HEALEY.—The trouble with the producers of molding sand has been, for a number of years, that the foundrymen want to buy cheap sand, and they won't pay us enough so that we can produce it the way they want it to give them good sand. As a rule, if they would allow the producers more money, they would get good sand; but the salesman goes in to sell them some sand and they say "Here is a farmer who came in and he can sell us some sand 25 or 50 cents a ton

cheaper than you can, and we will have to buy from him or you will have to meet his price; he has no overhead and can sell at a lower price." The result is we have to meet that competition and you cannot expect to get good sand.

L. L. ANTHES.—What is your test of good sand?

MR. HEALEY.—Well, it all depends on the conditions; practically no two foundrymen will agree on a test; no two will say that the same sand will answer their purpose; it all depends on the conditions and what they are going to make.

L. L. ANTHES.—The farmer might claim his sand is as good as yours.

MR. HEALEY.—Well, if the foundryman is satisfied, we can't help it.

H. M. LANE.—I do not want to take up a lot of time on this thing, but you have done something on sand and I want to say something that connects with what was said by the last speaker and what was said by Mr. Anthes. The molding sand industry of this country is divided into districts. In some districts there has grown up what might be called an art of digging sand, and those men who dig it know their business, and if the foundryman puts himself in their hands by the old method, they give him a very good product because they select and blend, but we have always had these pirate sand men who come in with a little deposit which they think is good, and they dig everything from grass to gravel and deliver it to you for sand. Then we have outside of that certain districts where the art of sand digging has not been developed. I know that I had to make a survey for a number of people, hunting for sands for them, and I have gone over, I presume, a hundred and fifty or two hundred sand pits in various parts of the United States. I believe it is very important that we develop a standard method of testing. I do not believe that the standard method for testing will become a universal method for some years yet, but I believe that the foundryman is a very foolish foundryman who allows his purchasing agent to purchase on price only.

H. B. TAYLOR.—The question has been raised here today about the different tests. They mean nothing to the sand

shipper, not a thing. We cannot employ the wonderful laboratory tests that we might employ in our sands. You know what nature has done in a bank of sand; you can go three feet and the bank changes instantly. We however go to considerable trouble, first in locating the deposits which we think are valuable deposits of sand; we invest our money; we take sands to the foundryman, and he tries them and they are perfectly satisfactory. Take our gravel, for instance, which you speak of; we have gone to the expense of putting in screens; we have one machine where we put it first into a large screen, then we have a second screen which runs on trunnions, and in that screen there are beater blades, because we find that the sticky, cohesive part of the gravel adheres to those trunnions, so we scalp them off and run them through another and the farmer right across from us knows that we are shipping out probably two or three or four hundred tons a day when things are going right, and he opens up a place and takes a sample in a cigar box and says to the foundryman "I am shipping right across from that man's sand deposits at 5 cents a ton less." After we have gone to all the trouble of putting up screens, buying up properties, et cetera, the cigar box sample, and 5 cents a ton will change you, and you will leave us and go right over to the independent shipper.

CHAIRMAN R. A. BULL.—In order that you may not have your remarks misinterpreted, would you mind stating whether you mean that the laboratory tests referred to, in the opinion of the sand producers, will be of no value?

H. B. TAYLOR.—They will be of value. Probably I should not have made that so broad. As I said the other day, we welcome standardization. I have not time enough to tell the different experiences I have had and that the other sand men had as to the sands which we thought were acceptable deposits in New York state and New Jersey and Pennsylvania. But frequently a man will pick up some sand miles and miles away from recognized deposits and a foundryman says it is the best sand he ever had. We don't know what to do. Mr. Lane referred to these collective groups of sand shippers. We all collect right around one another; one opens up a pit and we

all flock there. We are employing ordinary laborers; we pick from those men the most intelligent man we have to superintend the loading of our material. We welcome the day when we can put practical foundrymen in charge of our sand deposits. Today the men we employ never saw a foundry; they do not know anything about it. We go down there and spend hours with them trying to devote as much of our personal time to our different deposits as we possibly can, but it is a question of price, gentlemen. We are prepared to go the limit of expenditure for putting in machinery for blending sands and making them as near absolutely uniform as is possible for us to make them. We have never done it yet, though we have had plans drawn for years, but the foundrymen do not welcome that, they are not ready for it yet, because, as I have said and as Mr. Healey said, it was a question of price.

MR. MCKENNA.—I am neither a foundryman nor a sand man in the sense that these gentlemen who have been speaking to you would understand. I am very much and very vitally interested in the proper production of molding sands. I was very much interested indeed in the standards which are being set up, for in my experience I have run on to some very difficult sand problems. I had an experience during the present year in New Jersey which was the most discouraging situation I ever faced in the effort to produce a satisfactory molding sand and keep it satisfactory after continuous service. Now I think that the one thing perhaps which will eventually come out of this standardization will be forcing the necessity upon the sand producer of not only blending his sand but actually milling it. That is the one point that I want to contribute to this discussion this morning, but I want to assure you that it is not possible for the man who mills and screens and prepares sand properly, to compete with the man who shovels it out of the bank and delivers it to you unscreened, hit or miss as it may come today or tomorrow.

E. M. AYERS.—I have been serving foundrymen for 38 years on molding sand, and want to emphasize what Mr. Lane has said to you, that unless you separate the purchasing department from the operating department, this entire discussion,

this entire effort, is going to be futile. We find that regardless of how we try to serve, just as has been said, a man comes along with a cheap sand, the buyer buys it and the foundryman has to use it. I want to say another thing to you, that so far as the sand man is concerned—that there is absolutely no good will in the sand business since the war. I want that to go home, and I want you all to understand it. We who took care of the men at a cheap rate and fulfilled our contracts all during the war, were forgotten as soon as the war was over. I have checked it up with our fellow producers who feel the same way. I went into a place some time ago where we sold 400 cars of molding sand a year in 1916, 1917, 1918 and 1920, and they were nearly out of sand. They found they could buy sand for 20 cents a ton less than our price, and bought it. Then when I go to their plant, I find out that the sand is coming in and labor at 30 cents an hour is being used to put it through a machine, which made the cost of that sand three or four times the difference between our price and the price at which they bought that sand. When you tell that to the purchasing agent he says, "We are perfectly satisfied." When I go to the superintendent, he says, "We have to use what they tell us." The man further up says the dollar is what counts. When we open up a pit of sand and spend $25,000, $50,000, maybe $75,000 in getting ready to serve those who are our customers, that investment if not used for molding sand is practically worthless. And we may get 10 cents on the dollar on what we invest. If that deposit is good for 15 years, the investment is spread over that period, and when you add that to the cost of your production, it is a legitimate charge; the maintenance of the plant for that time is very high. Now after you carry that through and try to serve your customers, it is discouraging to hear a sand producer tell you the experience every sand man has had with the average foundry; but I am pleased to say that there are many foundrymen who are not that way.

We have put out this year a foundry efficiency man to take our sand into the foundry and show them how to use it; we have made castings without using facing and doing many other things, at our own expense. At some foundries we find

the proper response. We have done it in some cases without the knowledge of the purchasing agent, or we would not be permitted to do it. If you can bring about a co-operation between you who are practical men in the foundry industry, and the sand men, you will find a response from the sand men that will surprise you. We carry a test every day of our molding sand, a precipitation test, a screen test every week, to see how the pits are running, whether the veins are changing, whether the bonds are changing. Some men want 50 per cent and some a 60 per cent bond. We can come within two or three per cent of giving them what they want, but you cannot do that for nothing. If it is worth it, let the foundryman pay a proper price. I represent both the silica and the iron molding sand interests of our association and you will find from the molding sand people a great deal more united effort and willingness to co-operate and desire to keep service up to the standard which you should require, and also a willingness to accept any recommendations that are made by your Committee. If it costs money, we are willing to spend it, and whether we get it back is up to us. We are already spending some money; I was in a sand man's office some time ago, who has his record for over two years at periods all the way through, so that when the time comes that you want to set up a standard for a screen test or a precipitation test or a bond test, he will be able to say what his sand has done over this period. We started in a little later, but when this comes out, we can tell you the standard we set up; it is uniform, if that is worth anything to you, all right; if it is not, forget everything you have done here this morning and the work of this research committee. Nothing will be accomplished without a cordial response from you who are the practical men in your organization and the restriction of the purchasing agent. If you work along that line with the sand man, you will get those sands.

CHAIRMAN R. A. BULL.—I do not deplore the commercial note in this discussion, because it is appropriate to emphasize the fact that we are spending honest-to-goodness money in this work, spending it as judicially as possible. This committee of 40 men will be tremendously disappointed if ulti-

mately the information they secure cannot have a very practical value. We have got to justify it from the standpoint of dollars and cents in the future.

MR. PEALE.—I would like to ask Mr. Hanley if the method of deflocculation will be made public or whether it will be used privately to obtain sands according to the test as it will eventually come out.

CHAIRMAN R. A. BULL.—The complete description of all these testing methods will be given to every member of the American Foundrymen's Association, and possibly will have a good deal wider circulation than that. The idea is to benefit the entire industry just as quickly as possible. That method is not in shape yet for presentation.

H. M. LANE.—I wanted to bring out one prime point in regard to our molding sand deposits in this country. What Mr. Ayers has said in regard to his district is true; we have through that district a set of deposits of certain geological formation and it gives him a big volume of raw material, and that central part lends itself well to milling, and milling has been developed through there. The Albany deposits with their big flat layers, lend themselves more to blending than to milling, and the Southern district has never done anything hardly but dig, which is also true of the West; I do not know of any body in the West that has done anything but dig. I simply wanted to bring out this point as a distinction between what has been said on the Albany district, where you must dig a flat place and blend it, and what comes from other districts where we dig our sand in masses and blend them by milling.

R. F. HARRINGTON.—As a consumer of considerable quantity of molding sand at Boston on which we have a heavy freight rate against us, I just want to say that the message Mr. Ayers has given us is a vital one, and I believe that there is a new era coming. I believe that the sand producer is really going to have more co-operation on the part of the sand user than he has ever experienced before, because those few who have been willing to co-operate with the sand producer have found that in the long run it pays mighty well. So I think the

sand producer can feel very certain that the consumer will endeavor to set up a standard for his purchasing department and that they can depend on the consumer to stand by the man who gives quality and real service in the production of his molding sand.

EUGENE SMITH.—We are today in the position of the children at school; they do not teach them the A B C's first like they did in my day; they put up a picture of a horse, and the word "horse" after it, and the child learns the whole word. The same way with "cat" and the same way with "dog." Now we are in that position. We are trying to learn a whole word at once, and we are coming back to the alphabet, and are going to land somewhere. Do not depreciate the value of the work that your research committee is doing, but make use of it. Now I want you to consider me as I was 49 years ago in the foundry, shoveling sand, tempering it for our molder. After he poured the mold he had to have the sand prepared so that he could make another mold and get good castings. You are doing the same thing today; you have to do it, for the machine. I have seen within my time another school. The old foundryman, if he is here, remembers the time when we said you did not need a doctor in your business, and we also do not forget the chemist, who 20 or 25 years ago ridiculed that poor devil of a laborer in the pig iron foundry, when he broke the pig and charged according to the fracture. What was he doing? He was practicing a structural analysis which is today being combined in your laboratories, combining the chemist's work with the microscope. You are beginning to see that is exactly where you are going to land with your sand question. It would be of value to you to know that it would increase the volume of your business if all foundries had done the same as I have. In 1915 I had used or was told I had used 5000 tons of sand, and on practically the same melt in a later year we used 1500 tons of sand. How was it done? It was done simply by getting the proper sands in the foundry and using them together properly. When I was asked to write a paper for the Chicago Foundrymen's Club I asked myself the question "What will I write on?" I thought to myself, "There are three things re-

quired for a successful foundry of any kind. First, you want good equipment. It means equipment suitable for the class of work to be made. Next, you want good metal. By good metal I mean that you want metal suitable to the character and class of work which is to be made. Now the third thing you want is sand, and you know you want good sand. Did anybody ever hear of sand being too good? When we say good sand, we mean a tempered sand whether it is blended or wherever it comes from, you do not care. The table that I put out may have been inaccurate, but you know when you are with a foundry 20 years, you are not going to change sands 20 times, not reasonably; so you would not have access to many analyses, even if you had a laboratory. What is lacking is an interchange of communication between the foundry foreman and his superior officer. Let the superintendent be an intelligent means of intercommunication between his foreman and the purchasing department and the salesman, so that when they are talking sands, you will have some intelligence just the same as today when you are buying pig iron or coke or coal. When a man has a loss; what is the usual course? He immediately jumps to the conclusion "My sand was no good or my pattern was no good," and the sand man is not there and cannot defend himself and a good customer is lost. The proper means of communication would remove that condition. The sand distributor would not visit one foundry having in his case samples that belonged to an entirely different line of work, if he knew just the character of sand that particular plant wanted. My friend from Canada has a very difficult situation. I was up in Montreal last year, and they have a sand high in silica like all eastern sands. It is higher in silica than our Western sands, but if they look around locally, they will probably find a binder for the high silica sand, in their own district. In the state of Illinois, or, I might say generally, all the sands in the state of Illinois are high in bonding quality, and the difficulty is getting what you have in the East. If we could only get it by freight, we would be using Albany sand 50-50 with the Illinois sand, and if you could only get it here, you would be using 50-50 with the other. And not only that, but if we had

the proper means of determining properties you could probably go into Indiana and find identically the same sands as in the East. If any gentleman visits me any time, I will show him sand like the Albany sand in Indiana and Kentucky sands, and placed along side of each other, I defy you to tell which is which. Why do you go to France for sands when you have them right here in the States of Indiana and Kentucky and also in Wisconsin.

GEORGE F. PETTINOS.—I have only a few words to say. The first question is this; what is this research committee for? I would answer that from the foundryman's standpoint by saying it is up to that research committee to find the proper sands that will make the best castings for the foundryman and also to find the best methods for saving them. That is what this committee is to do for the foundryman and it is what it is to do for the sand shippers. This committee is to find specifications and state them clearly so that the producers will know exactly the kind of sand that will suit the particular line of work. Now that means co-operation all around. I think there is not a sand producer here who would not welcome that sort of co-operation, not only with the committee but with the foundryman, the user of these sands. The laboratory question has been touched on; I believe in that laboratory investigation. I do not think that anything has ever been accomplished worth while in the practical or the scientific world that has not been started by trained men who are accustomed to analysis and understand methods of investigation.

Primarily this committee has to decide what is a good molding sand. Now, to my mind, the requirements of molding sand can be reduced to just three points; you have to have a sand that will not shake out in the mold and which will stand up and conform to the shape of the mold; you have to have sand that will not melt, and furthermore you have got to have sand that will let the gas out. Now I do not know anything else connected with sand that is necessary outside of these three points. Now I would say that the bond, of course, is very, very important. You must have a bond that will not burn out; you must have a bond of such a nature that a very little

bit of it will cause the particles of sand to cohere. You cannot have a bond in that sand such that when you ram it, it closes up the interstices and will not let the gas out.

Second, I say that this committee ought to find the proportion between the particles of the sand that will enable that sand to stand up and not melt, and yet let the gases go through. For illustration, take coal—it is rather difficult to burn coal in fairly good sized chunks, but suppose you pulverize that coal and apply temperature to it, you get an explosion. Now the same thing applies to the sand; if you have round, large particles, they are much harder to mold. Of course I do not forget the chemical constituents. For instance, if you have a certain amount of oxide of iron, lime, et cetera, in connection with the siliceous materials, fluxing takes place the same as if you put the lime in a blast furnace, but outside of that I say the size of grain has everything to do with the standing up of the sand, the non-melting of the sand. Therefore this committee ought, by investigation, to find the proper size of those grains that will give a smooth surface and yet let the gases go through. By way of illustration suppose you had a cubic yard of cobblestones; the interstices are very large; you can run a mass of water through that. Now suppose you take those cobblestones and bring them down to the size of shot; you won't get the water through so fast, but that does not say that the aggregate interstices, the aggregate volume, is not equally as large as it was in the first place, where you had large cobblestones and large spaces between. If you just simply take that illustration and apply it to a mold when you pour the iron, if you use cobblestones, the gas will go out and so will the iron. When you reduce the size, you want to get it to a point where the interstices are not too large, where there are not too many indentations or too deep indentations rather, so that you would have a rough casting, but you do want them large enough to enable the spaces between to be of sufficient size to let the gases out. Now I think that perhaps the majority of foundrymen use a sand that is too fine. I think if that was investigated that a larger

size grain sand probably would give better results. There is one thing I do want to say and that is that the sand producer is thoroughly in accord with this Research Committee. For my part, I am not at all anxious about price; I believe that every foundryman who has sense will try and get the material that is best suited for his purpose, and I think will pay the price

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